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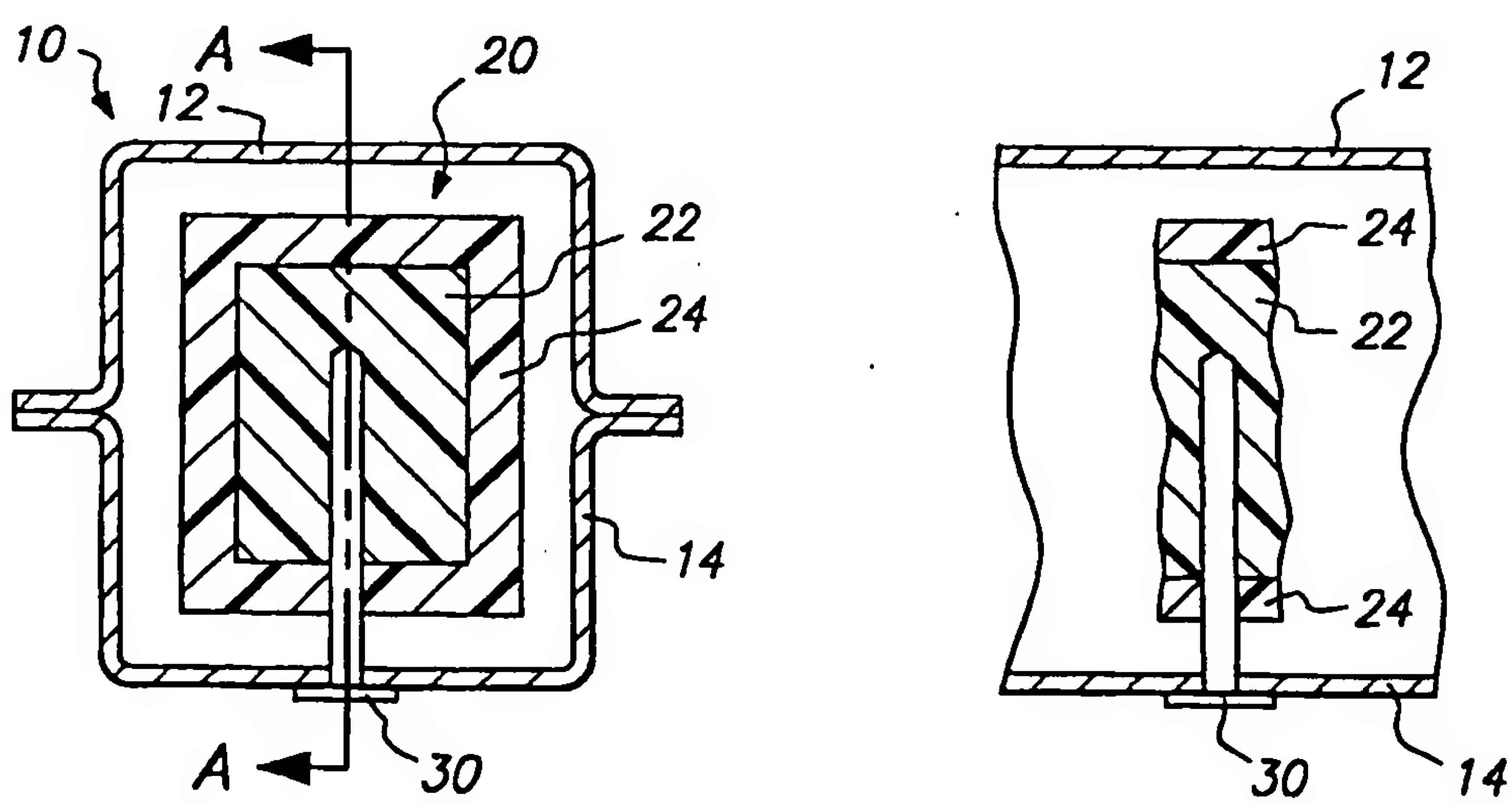

(57) Abstract

A planar cavity sealing article comprises: (a) at least one driver comprising a cross-linked foamable polymer, and (b) a sealer comprising an uncross-linked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the article

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CAVITY SEALING ARTICLE AND METHOD

TECHNICAL FILED OF THE INVENTION

This invention relates to sealing articles for cavities, and methods for making and using them. More particularly, this invention relates to sealing articles for channels in automobiles or other land vehicles, boats or other marine vehicles, aircraft or other aerospace vehicles, structures, including land and marine structures, and the like, wherever it is desirable to seal a cavity against the passage of air, moisture, fluids, particulates, and the like. In a particular aspect, this invention relates to the sealing of channels, such as pillars, in the body structure of automobiles and similar vehicles; and the invention will be discussed primarily with respect to that aspect.

BACKGROUND OF THE INVENTION

During the fabrication of automobiles, trucks, and similar vehicles, many body components present cavities that require sealing to prevent the ingress of moisture and contaminants that can cause corrosion of the body parts. This is especially true with respect to unibody structures, where a heavy frame is replaced by a structurally designed space frame that inherently presents a number of moisture- and contaminant-collecting cavities. These cavities also serve as passages through which road and engine noise and other sounds may be transmitted during normal use of the vehicle. For example, the upright post structure of a vehicle body defining a portion of a window opening presents an elongated cavity that can collect moisture and contaminants and also transmit sounds unless the cavity is at least partially filled with a sealant material that blocks the passage of moisture and debris and that also serves as a baffle for muting sounds that would otherwise be transmitted along the length of the cavity and then radiate into the passenger compartment of the vehicle. There are other irregular cavities in a vehicle body that desirably are sealed to prevent moisture and contaminants from entering that area and being conveyed to other parts of the vehicle body.

Many attempts have been made to seal these cavities; and some techniques and products for this purpose are described in US Patents Nos. 5,266,133 and 5,373,027

(Hanley et al.), 5,212,208 and 5,160,465 (Soderberg), 5,040,803 (Cieslik et al.), 4,989,913 (Moore, III), and 4,874,650 (Kitoh et al.), among others.

A currently favored technique in automobile cavity sealing is the use of a heat-activated sealing foam material. Typically, a mass of a material capable of expansion (foaming) at elevated temperatures, i.e. a thermoplastic mixture containing both a heat-activated foaming agent and a heat-activated crosslinking agent, is placed on a tray or other mechanical support, usually made from sheet metal or a molded high temperature thermoplastic, that is capable of being mechanically fastened within the cavity. Because automobile bodies are now typically coated by total immersion in phosphating, rustproofing, electrocoating, and other paint baths to ensure that the interiors of all open cavities are coated, the sealing article (the tray, together with the mass of foamable material), should not fill the cavity cross-section before foaming, so that the coatings may enter the cavity during immersion and drain from it after removal from the bath. As the automobile body is passed through an oven to cure the coating to the metal of the body, the foamable mass expands to fill the cavity cross-section and seal to the walls of the cavity. While this technique has proved generally satisfactory, it suffers from two principal disadvantages. First, because the foam material is not self-supporting during foaming, it is subject to sagging before the foam crosslinks, and therefore requires support. This problem is particularly severe when the axis of the cavity to be sealed is approximately horizontal, so that the foam material (which is perpendicular to the cavity axis) is approximately vertical, and the sagging therefore tends to limit expansion of the foam toward the upper parts of the cavity walls. The tray required to support the foam during expansion and sealing adds to both the weight and cost of the seal. Second, because the foamable material is supported during expansion, interfacial adhesion of the molten foaming material to the support restricts lateral expansion of the foam, so that greater expansion occurs perpendicular to the support (along the longitudinal axis of the cavity rather than towards the cavity walls). As a result, sealing may be incomplete, and a greater amount of foamable material is used in an attempt to ensure adequate sealing, also adding to both the weight and cost of the seal. This problem is particularly severe when the cavity to be sealed is highly irregular in cross-section or has a sharply acute angle,

when a considerable excess of foamable material may be used to attempt to ensure that the foam fills the cavity cross-section and penetrates to the vertex of the angle.

In certain uses, particularly in the sealing of the vertical pillars of automobile bodies, it may be desirable to be able to provide a drain passage within the pillar. For example, in automobiles with sunroofs, it is necessary to provide a drain passage for water which might otherwise accumulate in spaces around the sunroof. Usually, this drain passage is created by a drain tube from the sunroof area passing down one or both of the "A" pillars (the pillars on either side of the front window of the automobile). Thus a passage must be provided through any seal in that pillar. Three different solutions are currently used for this problem. One is to allow the pillar itself to serve as the drain passage and to provide a drainage plug through the cavity seal. The drainage plug has a tortuous path through which fluids may drain, but which is intended to reduce sound travel through the plug. This simple solution has the two disadvantages of allowing draining fluid to contact the inside of the pillar as it drains and of allowing sound infiltration, especially the infiltration of high frequency sound, through the drain plug since the tortuous path is still open. A second solution is to use a conventional seal with a hole, and a drain hose passing through the hole. Here the disadvantages of the drain plug are avoided, but the need for the hose to be emplaced before the vehicle frame is fully assembled means that a hose capable of withstanding the high temperatures encountered in the paint bake ovens must be used, increasing the cost. A third solution is to leave the pillars open through the painting process, then install a low cost hose through the pillar and seal it in place by injection of a foaming material, such as a two-part urethane, into the pillar. This solution also provides an effective seal, but at the increased cost of capital equipment for preparation and injection of the urethane foam, ventilation, etc., and with the need for an additional step in the vehicle assembly process.

It would be desirable to produce a cavity sealing article, especially a sealing article for use in a channel in a land, marine, or aerospace vehicle, such as a pillar in the body structure of an automobile or similar vehicle, that could be prepared readily and inexpensively, would be readily handleable and emplaceable within a cavity to be sealed without requiring special tooling, would be readily activatable by elevating the cavity temperature to such temperatures as are commonly encountered in operations on the

vehicle body (e.g. 115°C to 250°C for automobile paint ovens), and, on activation, would provide an effective seal against infiltration of air, moisture, other undesirable fluids and particulates, and sound. Desirably, such a sealing article would also permit the passage of drain hoses and the like through the seal. It would also be desirable to produce a multiple-layer cavity sealing article having the same ease of manufacture and use and providing an even more effective sound seal.

BRIEF SUMMARY OF THE INVENTION

In a first aspect, this invention provides a planar cavity sealing article comprising:

(a) at least one driver comprising a crosslinked foamable polymer, and

(b) a sealer comprising an uncrosslinked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the article.

In particular, in this first aspect, this invention provides a planar cavity sealing article for use in a longitudinally extending cavity defined by cavity walls, the cavity having a cross-section within the cavity walls which is to be sealed at a predetermined location, the article comprising:

(a) at least one driver comprising a crosslinked foamable polymer, and

(b) a sealer comprising an uncrosslinked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the article;

the article having a size and shape such that the article incompletely occupies the cross-section of the cavity at the predetermined location and having expansion and sealing properties such that, when the article is placed at the predetermined location within the cavity and foamed, the foamed sealer is forced into intimate and sealing contact with the cavity walls.

Especially, in this first aspect, this invention provides a cavity sealing article for use in a longitudinally extending cavity defined by cavity walls, the cavity having a cross-section within the cavity walls which is to be sealed at a predetermined location, the article comprising:

(a) a planar cavity sealing layer comprising:

(1) at least one driver comprising a crosslinked foamable polymer, and

(2) a sealer comprising an uncrosslinked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the layer; and

(b) a support structure adapted to fit within the cavity and orient the article within the cross-section at the predetermined location,

the article having a size and shape such that the article incompletely occupies the cross-section of the cavity at the predetermined location and the sealing layer having expansion and sealing properties such that, when the article is placed at the predetermined location within the cavity and foamed, the foamed sealer is forced into intimate and sealing contact with the cavity walls.

In a second aspect, this invention provides a multiple-layer cavity sealing article comprising:

(a) a plurality of planar sealing layers, each sealing layer independently comprising:

(a) at least one driver comprising a crosslinked foamable polymer, and

(b) a sealer comprising an uncrosslinked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the layer; and

(b) a support structure supporting the plurality of sealing layers in spaced-apart relationship.

In particular, in this second aspect, this invention provides a multiple-layer cavity sealing article for use in a longitudinally extending cavity defined by cavity walls, the cavity having a cross-section within the cavity walls which is to be sealed at a predetermined location, the article comprising:

(a) a plurality of planar sealing layers, each sealing layer independently comprising:

(a) at least one driver comprising a crosslinked foamable polymer, and

(b) a sealer comprising an uncrosslinked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the layer; and

(b) a support structure adapted to fit within the cavity and orient the article within the cross-section at the predetermined location, the support structure supporting the plurality of sealing layers in spaced-apart relationship,

the article having a size and shape such that the article incompletely occupies the cross-section of the cavity at the predetermined location and the sealing layers having expansion and sealing properties such that, when the article is placed at the predetermined location within the cavity and foamed, the foamed sealers are forced into intimate and sealing contact with the cavity walls.

In a third aspect, this invention provides a method of sealing a cavity by use of the cavity sealing article of the invention.

In a fourth aspect, this invention provides a method of making the cavity sealing article of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view showing a first embodiment of the cavity sealing article of this invention emplaced within a cavity.

FIG. 2 is a cross-sectional view along line A-A of FIG. 1, parallel to the longitudinal axis of the cavity.

FIG. 3 is a cross-sectional view showing the cavity sealing article of FIG. 1 after foaming.

FIG. 4 is a cross-sectional view showing a second embodiment of the cavity sealing article of this invention emplaced within a cavity.

FIG. 5 is a cross-sectional view showing a third embodiment of the cavity sealing article of this invention emplaced within a cavity.

FIG. 6 is a cross-sectional view showing a fourth embodiment of the cavity sealing article of this invention emplaced within a cavity.

FIG. 7 is a cross-sectional view showing a fifth embodiment of the cavity sealing article of this invention emplaced within a cavity.

FIG. 8 is a cross-sectional view showing a sixth embodiment of the cavity sealing article of this invention emplaced within a cavity.

FIG. 9 is a cross-sectional view showing the first embodiment of the cavity sealing article of this invention emplaced upon a support plate within a cavity.

FIG. 10 is a cross-sectional view along line A-A of FIG. 9, parallel to the longitudinal axis of the cavity.

FIG. 11 is a cross-sectional view showing a seventh embodiment of the cavity sealing article of this invention with an aperture therethrough emplaced within a cavity.

FIG. 12 is a cross-sectional view along line A-A of FIG. 11, parallel to the longitudinal axis of the cavity.

FIG. 13 is a cross-sectional view showing an eighth embodiment of the cavity sealing article of this invention with a grommet therethrough emplaced within a cavity.

FIG. 14 is a cross-sectional view along line A-A of FIG. 13, parallel to the longitudinal axis of the cavity.

FIG. 15 is a cross-sectional view showing a ninth, multiple-layer, embodiment of the cavity sealing article of this invention emplaced in a cavity, the cross-section being parallel to the cavity axis.

FIG. 16 is a cross-sectional view showing a tenth, multiple-layer, embodiment of the cavity sealing article of this invention emplaced in a cavity, the cross-section being parallel to the cavity axis.

FIG. 17 is a perspective view showing an eleventh, multiple-layer, embodiment of the cavity sealing article of this invention.

FIG. 18 is a cross-sectional view of the eleventh embodiment of the cavity sealing article of this invention emplaced in a cavity, the cross-section being parallel to the cavity axis.

FIG. 19 is a cross-sectional view of the eleventh embodiment of the cavity sealing article of this invention after foaming and expansion.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

For simplicity and ease of understanding, the invention will be described and illustrated generally with respect to a cavity sealing article of this invention having only a single sealing layer, including the case where the sealing layer itself forms the cavity sealing article, and where the article or sealing layer(s) of the article comprise only one

driver; however, specific illustration of cavity sealing articles having more than one sealing layer and articles or sealing layers having more than one driver will also be given.

Referring to the drawings, where like numerals denote like elements of the invention, FIG. 1 is a cross-sectional view showing a first embodiment of the cavity sealing article of this invention emplaced at a predetermined location within a cavity, the longitudinal axis of which is perpendicular to the page. The axis of the cavity may be oriented in any direction: horizontal, oblique, or vertical; so that the cross-section that is to be sealed at the predetermined location may be, correspondingly, vertical, oblique, or horizontal. The cavity shown generally as 10 is defined by a pair of cavity wall forming members 12 and 14 which may be fastened together by any suitable means (not shown). The planar cavity sealing article shown generally as 20 comprises a single sealing layer of a single crosslinked foamable polymer driver 22 surrounded in the plane of the article by and in intimate contact with an uncrosslinked foamable polymer sealer 24. The article 20 is positioned within the cavity 10 by mounting on a stud 30 projecting through one of the cavity walls. FIG. 2 shows the article of FIG. 1 in a further cross-sectional view, where the longitudinal axis of the cavity is parallel to the page. On activation of the article by the application of a sufficient temperature for a sufficient time, the driver 22 foams to expand and force the sealer 24, which also foams and expands, into contact with the cavity walls, thereby sealing the cavity. FIG. 3 shows the cavity sealing article of FIG. 1 after foaming, where the driver 22 has foamed and expanded to more substantially fill the cavity cross-section; and the sealer 24, which has also foamed and expanded, has been forced into sealing contact with the cavity walls. FIG. 4 shows a second embodiment of the cavity sealing article of this invention, also having only a single driver, but where the driver is of non-uniform shape with exaggerations or protrusions in directions in which it is desired to provide an especially pronounced "push" to the sealer by the foaming and expansion of the driver. FIGS. 5, 6, and 7 show three more embodiments of this first, single-layer, aspect of the cavity sealing article of this invention in cross-section, where each of the articles shown generally at 20 comprises a plurality of drivers 22 with a sealer 24 in intimate contact with and substantially surrounding the plurality of drivers in the plane of the article.

Composition of the cavity sealing article or sealing layer(s) of the cavity sealing article

Suitable compositions for the cavity sealing article, or for the or each sealing layer of the cavity sealing article, of this invention will be foamable polymer compositions having a foaming temperature appropriate to the temperature range of intended application, for example a foaming temperature within the range of temperatures to be encountered in bake ovens for vehicle bodies, and the like. Such compositions will contain a base polymer and a blowing agent to cause foaming of the polymer. They will typically also contain fillers, antioxidants, flame retardants, and/or other stabilizers such as are conventional in polymeric articles, and may contain pigments, plasticizers, adhesion promoters, activators for the blowing agents, and the like.

The sealer portion of the article or sealing layer(s), sometimes referred to elsewhere in this application simply as "the sealer", may, and preferably will, contain a chemical crosslinking agent to strengthen the resulting foamed polymer, and may also contain a tackifier to maximize adhesion of the article to the cavity walls on foaming. If the sealer and the driver(s) are not made in a unitary fashion, but are assembled before crosslinking of the driver(s), for example by comolding or coextrusion of the driver(s) and sealer portions of the article or sealing layer(s), and the driver(s) are to be crosslinked by radiation, then the sealer may contain an agent chosen to prevent radiation crosslinking, an "anti-rad", for example a free-radical quencher such as an amine, so that the whole article or sealing layer may be irradiated with only the driver(s) being crosslinked by the radiation. The sealer is uncrosslinked before foaming, by which is meant that it is either totally free of crosslinking or has such a low degree of crosslinking that it substantially retains the foaming and adhesive characteristics of an uncrosslinked polymer. Desirably, the sealer becomes crosslinked on foaming, as discussed further later in the application, as this provides additional stability to the foam, but it is within the scope of the invention that the sealer may be uncrosslinked (as defined immediately above) even after foaming.

The at least one driver portion of the article, or of the or each sealing layer of the article, sometimes referred to elsewhere in this application simply as "the driver" or "the drivers", which are crosslinked, will typically contain either or both of a chemical crosslinking agent and a radiation crosslinking promoter, a "pro-rad", to enhance radiation crosslinking of the driver. Where the at least one driver portion of the article or layer(s) is

chemically crosslinked, the crosslinking agent chosen will be one having an activation temperature substantially below the activation temperature of the blowing agent so that the driver may be crosslinked before any foaming occurs. When the at least one driver portion is radiation crosslinked, such as by exposure to electron beam irradiation, the driver portion will typically contain a radiation crosslinking promoter; the amount and type of which may be chosen depending on the polymer composition. When the at least one driver is crosslinked by radiation, the extent of the irradiation will depend on the material of the driver(s) (the polymer, additives, etc.), the type and quantity of radiation crosslinking promoter, the thickness of the article, etc. Typical irradiation dosages for electron beam irradiation will lie between 0.25 and 20 Mrad, preferably between 0.5 and 10 Mrad, and more preferably between 2 and 6 Mrad.

If the article or sealing layer comprises a plurality of drivers, it will generally be convenient for all of the plurality of drivers to be crosslinked to an equal extent so that their expansion properties are the same. For example, in the third and fourth embodiments of the article shown in FIGS. 5 and 6, where the drivers are of uniform size and are arranged regularly within the plane of the article, it will be convenient for the plurality of drivers to be crosslinked to an equal extent. However, it is within the scope of this invention that the drivers may not be crosslinked to an equal extent, if desired. For example, in FIG. 7, where there are two sets of drivers, an inner first set of two drivers 221 surrounded by an outer second set of four drivers 222, it may be advantageous for the drivers in the inner set and outer set to be crosslinked to different extents so that they possess different expansion properties. This may be done, for example, by selective irradiation. For example, if it is desired that the inner set of drivers be more heavily crosslinked, such as by being irradiated to 6 Mrad, the outer set of drivers be less heavily crosslinked, such as by being irradiated to 3 Mrad, and the sealer uncrosslinked (unirradiated), then a sheet of foamable polymeric composition forming the article may be cut to the desired shape for the article, masked to expose only the region which will become the inner set of drivers and the masked article irradiated with 3 Mrad, the first mask removed and a second mask, exposing those regions which will become the inner and outer sets of drivers, placed over the article, and the re-masked article then irradiated

with a further 3 Mrad. The resulting article will have two sets of drivers having different extents of crosslinking and an uncrosslinked sealer.

Although it is not required by this invention that the compositions of the foamable polymers of the at least one driver and the sealer of the article or sealing layer(s) be the same, they should be compatible so that the resulting article or layer provides an optimal seal when the article is used.

It may be convenient for manufacture that the compositions of the foamable polymers of the at least one driver and sealer should be the same; and it may be further convenient that the article or sealing layer(s) should be formed from a single piece of such a foamable polymeric composition. Such a manufacture is discussed further later in this application and in the Examples. In this case, the at least one driver portion of the article or sealing layer will typically be crosslinked by radiation, and the foamable polymeric composition will contain both the chemical crosslinking agent for the sealer and desirably will also contain a radiation crosslinking promoter to enhance radiation crosslinking of the at least one driver.

Suitable base polymers may include a wide range of polymers, typically chosen for a particular application so that the resulting article will foam at a convenient temperature for sealing of the cavity to be sealed and will be stable under intended use conditions. A suitable base polymer or mixture of polymers will thus have a softening point below the desired temperature of foaming in the absence of crosslinking, for example at a temperature at least 50°C below the desired foaming temperature. The melt flow index, MFI, as measured by ASTM D-1238-95, of the polymer or mixture of polymers will desirably be from 0.5 to 10, preferably from 3 to 7, and in any event will desirably be chosen to give an appropriate degree of expansion of the resulting article during foaming.

Suitable polymers thus include olefinic polymers such as very low density polyethylene, low density polyethylene, medium density polyethylene, high density polyethylene, polyethylenes or ethylene copolymers prepared by metallocene polymerization, such as Exact [Exxon] and Engage [Dow], ethylene copolymers such as ethylene-vinyl acetate copolymer, ethylene-methacrylic acid copolymer, ethylene-acrylic acid copolymer, ethylene-butyl acrylate copolymer, ionomers, such as Surlyn [duPont]

and Iotek [Exxon], ethylene terpolymers such as ethylene-vinyl acetate-methacrylic acid copolymer, elastomers such as ethylene-propylene rubber, EPDM, nitrile rubbers, butyl rubbers, chloroprene, chloropolyethylene, polyacrylate elastomers, chlorosulfonated polyethylene, thermoplastic elastomers, and fluoropolymers such as polyvinylidene fluoride, ethylene-tetrafluoroethylene copolymer, fluorinated ethylene-propylene copolymer, poly(chlorotrifluoroethylene), ethylene-chlorotrifluoroethylene copolymer, etc., and mixtures of any two or more of the above.

For example, a suitable polymer or mixture of polymers for use in a cavity sealing article or sealing layer for use in the automobile industry, where bake oven temperatures will be in the range of 115°C to 250°C, e.g. around 160°C, may have a softening point below about 100°C, preferably below 90°C, in the absence of crosslinking. Such polymers may include ethylene-vinyl acetate copolymer (EVA), ethylene-methyl acrylate copolymer (EMA), and the like, optionally admixed with each other or with such polymers as low density polyethylene and/or ionomers. An exemplary polymer is EVA having a vinyl acetate (VA) content between 5% and 45%, especially between 15 and 35%, particularly between 20% and 30%.

Suitable fillers for the composition of the sealing article or sealing layer include inorganic fillers such as zinc oxide, barium sulfate (Huberbrite), calcium carbonate, magnesium hydroxide, alumina trihydrate, and the like; at a concentration up to about 40 parts per 100 parts of the base polymer.

The blowing agent is chosen so as to effect foaming and expansion of the article or sealing layer(s) at an elevated temperature normally present during the manufacture of the product containing the cavity to be sealed; for example, at a temperature normally present during passage of an automobile body through a paint bake oven (typically 115°C to 250°C). Suitable blowing agents will include from 1 to 15 parts per 100 parts of base polymer of an azodicarbonamide or benzenesulfonyl hydrazide. Suitable azodicarbonamide blowing agents include Celogen® AZ 130 or 3990; and suitable modified azodicarbonamide agents include Celogen® 754 or 765, all from Uniroyal Chemical. Suitable benzenesulfonyl hydrazide blowing agents include p,p'-oxybis-(benzenesulfonyl hydrazide), sold as Celogen® OT, and p-toluenesulfonyl hydrazide, sold as Celogen® TSH, both also from Uniroyal. The blowing agent may also be made up of a

combination of agents depending on the degree of expansion desired for a particular application; and may also include a blowing agent activator such as diethylene glycol, urea, dinitrosopentamethylenetetramine (DNPT), and the like. Certain fillers, such as zinc oxide (Kadox), may also act as activators for the blowing agent. The amount of activator added will depend on the choice of blowing agent and the amount of expansion required.

Flame retardants may also be present, of such kinds and at such concentrations as will provide flame retardancy for the article. These may include halogenated flame retardants such as the polybrominated aromatics (e.g. decabromobiphenyl), and the like, for example in combination with inorganic materials such as antimony trioxide; or may include non-halogenated flame retardants, such as the magnesium hydroxide and alumina trihydrate previously mentioned as fillers.

The chemical crosslinking agent is preferably a free radical crosslinking agent compatible with the base polymer of the article or sealing layer(s). Preferred chemical crosslinking agents are peroxides, such as bis(t-butylperoxy)diisopropylbenzene, 1,1-di-t-butylperoxy-3,3,5-trimethylcyclohexane, 4,4-di-t-butylperoxy n-butyl valerate (Trigonox), dicumyl peroxide (Dicup), and the like. In most cases, the chemical crosslinking agent is provided at 1 to 5 parts per 100 parts of base polymer.

The blowing agent and the chemical crosslinking agent will be chosen so that the chemical crosslinking agent has an activation temperature approximately that of the blowing agent. For example, it may have an activation temperature slightly below that of the blowing agent, so that the foam maintains stability during expansion,; but desirably the kinetics of the crosslinking and foaming reactions are such that the sealer of the article or sealing layer(s) expands and foams on heating, and adheres to the walls of the cavity, before the resulting foam is completely crosslinked by action of the chemical crosslinking agent. Desirably, the activation temperature of the blowing agent will be chosen so that the blowing agent is not easily accidentally activated (such as by mixing at a temperature above the optimal mixing temperature, during welding or other forming of a cavity in which the sealing article is emplaced, or during phosphating, painting or other coating treatments, or drying of such coatings) but is only activated when it encounters

temperatures in which it is desired that the sealing article should foam, such as are present in bake ovens.

The radiation crosslinking promoter may be chosen from among those conventionally used to promote the crosslinking of polymers, such as triallyl cyanurate (TAC), triallyl isocyanurate (TAIC), triallyl trimellitate, triallyl trimesate, tetraallyl pyromellitate, the diallyl ester of 1,1,3-trimethyl-5-carboxy-3-(4-carboxyphenyl)indane, trimethylolpropane trimellitate (TMPTM, Sartomer 350), pentaerythritol trimethacrylate, tri(2-acryloxyethyl) isocyanurate, tri(2-methacryloxyethyl) trimellitate, and the like, and combinations thereof.

The tackifier, if present, will be chosen to enhance the tackiness of the outside surface of the article or sealing layer(s), in particular the periphery of the article or sealing layer(s) which will come into contact with the cavity walls, on expansion but not such that the outer surface exhibits tackiness after formation of the article and before expansion, since it is generally desirable that the outer surface of the article should be dry and non-tacky during initial placement of the article in the cavity. Desirably, to enhance the adhesive qualities of the base polymer at the temperature of expansion, the tackifier will have a relatively low molecular weight, no significant crystallinity, a ring-and-ball softening point above at least 50°C (and preferably higher, near the softening point of the base polymer), and will be compatible with the base polymer and other polymers present. The tackifier may be present in up to 30 parts per 100 parts of base polymer. Suitable tackifiers include novolak resins, partially polymerized rosins, tall oil rosin esters, low molecular weight aromatic thermoplastic resins, Picco® and Piccotac® resins from Hercules Chemical, and the like.

Antioxidants, adhesion promoters, plasticizers, pigments, and the like may also be employed in conventional amounts.

Exemplary formulations include:

Ingredient	Formulation, parts by weight A	B	C	D
Evatane 28-05 (EVA)		100		100
Elvax 470 (EVA)	100		100	
Irganox 1076 (antioxidant)	2	2	2	2
Kadox 911 (ZnO)	30	30		
Huberbrite 7 ($BaSO_4$)			30	30
Piccotac 95 (tackifier)				30
Varox 231 XL (chemical crosslinking agent)	2.5	1.5	2.5	1.5
Celogen TSH (blowing agent)		10		10
Celogen OT (blowing agent)	10		10	
Sartomer 350 (radiation crosslinking promoter)	5	5	5	5

Of these formulations, formulations A and C are particularly applicable to the manufacture of the sealer portion of a cavity sealing article or sealing layer of a cavity sealing article of this invention, while formulations B and D are applicable to the manufacture of both the driver and sealer portions of a cavity sealing article or sealing layer.

The composition may be prepared by methods conventional in the art of polymer blending, such as by mixing in a high shear mixer such as a Banbury or Brabender type mixer, with care being taken to ensure that the temperature of the blend does not rise to such an extent that the chemical crosslinking agent or blowing agent are activated. Typically, the base polymer, other polymers/tackifier (if present), and antioxidant are added first, and blended to homogeneity. The filler, adhesion promoter, pigments (if present) may be mixed with the base polymer, or may be added after the base polymer has been softened by mixing. These first mixing stages are not particularly temperature-sensitive. Once all ingredients other than the blowing and crosslinking agents have been added and fully blended, however, temperature control becomes important as these last agents are added. Accordingly, the mixer is cooled so that the temperature of the composition does not exceed about 95°C, and more preferably does not exceed about 80°C; the blowing agent(s), accelerator(s), crosslinking agents, and any plasticizers are

added, and the resulting composition is subjected to high shear mixing under controlled temperature conditions until the composition is homogeneous. The composition may then be cooled, for example by processing through a two-roll mill with cooled rollers.

The resulting bulk composition may then be formed into the appropriate shape for the cavity sealing article of this invention by any appropriate means. For example, it may be extruded or rolled into sheets for cutting, extruded into rods of a desired cross-sectional configuration to be subsequently sectioned into the articles, molded into desired shapes, or pelletized for later molding or extrusion.

The particular composition used to make the cavity sealing article or sealing layer(s) of the cavity sealing article of this invention is not critical; and a person of ordinary skill in the art should have no difficulty, having regard to that skill and this disclosure, including the references cited here, in determining a suitable formulation to prepare a cavity sealing article or sealing layer of this invention or in optimizing such a composition for a particular application.

Manufacture of the cavity sealing article or sealing layer

Although it is within the contemplation of this invention that a single sealing article or sealing layer of an article of this invention may have expansion and sealing properties so that it may be used to seal a range of cavities of different sizes or shapes, more typically a cavity sealing article or sealing layer is formulated and shaped specifically for use in a particular cavity which is intended to be sealed. This is especially true in automobile or other vehicle manufacture, where cavities may be of very different cross-sections, and the quality of the seal is of considerable importance to provide a moisture, sound, and particulate barrier.

The thickness of the cavity sealing article or sealing layer of this invention, by which is meant the dimension perpendicular to the plane of the article or layer prior to foaming, will typically be between 3 mm and 13 mm, more typically between 5 mm and 8 mm. In a single-layer article, if the article is not provided with a support structure, such as the support plate seen in FIG. 10, for example, a relatively greater thickness may be desirable to provide adequate structural rigidity during manufacture and use; if the article

is provided with a support structure or is a multiple-layer article, then a relatively lesser thickness may be appropriate.

The cavity sealing article or the sealing layer(s) of the cavity sealing article of this invention, as previously described, comprises at least one foamable crosslinked driver substantially surrounded by a foamable uncrosslinked sealer, the shape and size of which will be chosen based on the cavity cross-section and the foaming properties of the article or layer(s). The article or layer(s) will typically have a cross-section that is comparable in shape to the cavity to be sealed, but between about 45% and 85% of the linear dimensions, typically about 55% to 75% of the linear dimensions, of the cavity.

Because the filling of the cavity cross-section is provided primarily by the at least one driver of the article or sealing layer, rather than by the sealer (which is much softer at the temperature of foaming), the cross-section of the at least one driver of the article or sealing layer will desirably be chosen so that, on expansion, the driver(s) alone would substantially but not completely fill the cavity cross-section; for example, the expanded driver(s) will have linear dimensions between 40% and 100% of the cavity dimensions, especially between 70% and 95% of the cavity dimensions. Too small a driver or drivers may provide insufficient filling of the cavity cross-section for the softer sealer portion to fill the remaining space, while too large a driver or drivers may buckle within the cavity when fully expanded thereby potentially damaging the seal. For a driver portion having a linear expansion of 200% (a volume expansion of 800%), then, suitable linear dimensions for the driver may be from 20% to 50%, especially 35% to 45% of the linear dimensions of the cavity; for a driver having a linear expansion of 230% (a volume expansion of 1200%), suitable linear dimensions may be from 18% to 45%, especially 30% to 40%, etc. Especially if the cavity is of irregular shape, the configuration of the driver portion may be exaggerated in the direction of shape irregularities, especially vertices, in the cross-section of the cavity, to ensure that the sealer portion is driven completely into these irregularities and vertices and the resulting foam completely fills and seals the cavity. This is shown in FIG. 4, where, although the cross-section of the sealing article as a whole is the same as that of the sealing article of FIG. 1, the single driver portion 22 of the sealing article 20 comprises exaggerations 22A through 22F in the direction of the vertices of the cavity to assist in filling these vertices. The sealer will relatively uniformly

surround the driver(s) in the plane of the article or layer and be of such a size that it provides sufficient sealing (i.e. as yet uncrosslinked) foam during expansion to completely fill all spaces between the driver(s) and the cavity walls and, desirably, adhere to them. The optimal size of the sealer will therefore depend on such factors as the material of the sealer, its extent of expansion, the extent to which the expanded driver(s) will fill the cavity, and the like.

The width of the sealer surrounding the driver(s) may be varied between different portions of the article, depending particularly on the complexity of the shape of the cavity to be sealed. For example, if the cavity is of relatively regular shape and the cavity walls are relatively smooth (lacking in sudden changes in direction), then a relatively greater clearance between the periphery of the article or sealing layer(s) and the cavity walls may be desirable; such as to permit the ready flow of paint when the cavity to be sealed is an automobile pillar painted by total immersion. In such a case, the proportion of the article or layer(s) comprising the driver(s) may generally be greater and, correspondingly, the width of the sealer will be less. However, if the cavity is narrow and/or of relatively irregular shape, then a narrower clearance between the periphery of the article or sealing layer(s) and the cavity walls may be desirable to ensure adequate filling of the cavity; and in such a case, the proportion of the article or layer(s) comprising the driver(s) may be smaller and the sealer be of relatively greater width. Thus a cavity of complex shape may be filled by a cavity sealing article of this invention with different clearance gaps between the article or sealing layer(s) and the walls of the cavity and sealer widths at different locations in the article.

Typically, the article or sealing layer(s) will be sized not directly as a proportion of the dimensions of the cavity at the predetermined location that is to be sealed, but by considering a certain clearance between the article or layer(s) and the cavity walls at the predetermined location, for example from 1 mm to about 8 mm, for example, about 3 mm to 5 mm, depending on the size of the cavity and the complexity of the cavity shape, and then calculating from the desired clearance and the resulting size of the article the extent of expansion that will be required to seal the cavity, taking into account the desirability of the expanded driver(s) substantially filling the cavity at the desired location with the sealer providing primarily the sealing between the article or layer(s) and the cavity walls.

Because the extent of expansion of the foamable polymeric material may conveniently be varied by both the amount of blowing agent that is used and by the extent of crosslinking of the driver(s), it will be possible to optimize the size and properties of the article or layer(s) to fill the cavity.

Conveniently, the cavity sealing article or the or each sealing layer of the article is manufactured in the form of a flat sheet having a shape corresponding generally to the cross-sectional shape of the cavity to be sealed, but smaller in linear dimension. In such a case, it is particularly convenient to manufacture the article or layer(s) from a foamable polymer composition containing both a chemical crosslinking agent for the sealer and a radiation crosslinking promoter for the driver portion or portions of the article or layer(s), as previously described. A sheet of foamable polymeric material is simply cut to the final dimensions of the article or layer(s), or the article or layer(s) are molded to the desired shape from the foamable polymeric material, and the driver portion or portions are selectively crosslinked by masking that portion of the piece which will become the sealer of the article or layer(s), so that only that portion of the piece that will become the driver or drivers of the article or layer(s) are crosslinked. The sealer portion and driver portion(s) of the article or layer(s) may also be cut separately from the same or different sheets of foamable polymeric material, and the resulting driver(s) and sealer assembled into the cavity sealing article of this invention. In this case, the sheet from which the driver(s) are cut may be crosslinked as a sheet before the driver(s) are cut from it, or the driver(s) may be crosslinked after cutting from the sheet. Other methods of manufacturing the cavity sealing article or sealing layer(s) thereof are also possible, such as extruding a rod of the foamable polymeric material of the driver(s) to a cross-section desired for the driver(s), crosslinking them, subsequently extruding around those rod(s) the foamable polymeric material of the sealer, then sectioning the resulting composite rod into a plurality of cavity sealing articles or layers; coextruding the driver(s) and sealer in the appropriate shapes, sectioning, and crosslinking the driver(s); molding the driver(s) and sealer either as a unitary piece of the same material or comolding two different materials for the driver(s) and sealer, etc. It is also within the scope of this invention that the sealer may also surround the driver in the direction of the cavity axis as well as in the cavity cross-section, although such embodiments are not shown.

It will be apparent that particular manufacturing techniques may be more appropriate for particular designs of the article or sealing layer(s). For example, although it may be convenient to physically assemble an article or sealing layer of the article from two separate pieces of material, one for the already-crosslinked driver and one for the sealer, when there is only a single driver, such a technique may be less convenient when an article or sealing layer is to contain a plurality of drivers, especially in the case of an embodiment such as that shown in FIG. 6 where there are a large number of drivers. However, techniques such as coextrusion and sectioning may be appropriate for such embodiments. A convenience in manufacturing an article or sealing layer with a large plurality of drivers, such as the embodiment of FIG. 6, may be in manufacturing a sheet of foamable polymeric material, irradiating it in a pattern to produce the drivers, and then cutting the sheet into pieces of appropriate shape for the desired article or sealing layer. This patterned irradiation and cutting may be done in such a way that the drivers form a regular pattern within the article or layer, such as is shown in FIG. 5; or it may be done in such a way that the drivers lie in no particular orientation with respect to the article or layer, such as is shown in FIG. 6, where it may be seen that not all of the periphery of the article is provided by sealer material.

The sealer substantially surrounds the at least one driver in the plane of the article or sealing layer to maximize the sealing efficiency of the article or layer when it is used, as the material of the sealer typically provides greater adhesion to the cavity walls than the material of the driver(s). By "substantially surrounds" is meant that the periphery of the article or layer in the plane of the article or layer should be provided primarily by the sealer. In particular, when the article or layer has only a single driver, it is desirable that the driver be completely surrounded by the sealer in the plane of the article or layer. Such a situation is seen in FIGS. 1 and 4, for example. When the article or layer has a plurality of drivers, it is also desirable that the drivers be completely surrounded by the sealer in the plane of the article or layer; and this is seen in FIGS. 5 and 7. However, for convenience in manufacture of the article or layer when the article or layer has a plurality of drivers and has been cut from a sheet of foamable polymeric material that has been selectively irradiated in a patterned manner such as in FIG. 6, as discussed above, a part of the periphery of the article or layer may be provided by driver material. In this

instance, it is desirable that the patterning of the drivers on the sheet and/or the cutting of the article or layer from the sheet be such that an article or layer cut from the sheet will have less than 50%, preferably less than 30%, more preferably less than 20% of the periphery provided by driver material; and that no large section of the periphery be provided solely by driver material.

Typically, a multiple-layer cavity sealing article of this invention will have two sealing layers, but this invention also contemplates articles having more than two sealing layers. For simplicity, and because the invention and its manufacture and use is adequately described by an article having only two layers, the drawings illustrate the invention only with reference to two-layer cavity sealing articles; however, a person of ordinary skill in the art will have no difficulty, having regard to that skill and this disclosure, in manufacturing and using a multiple-layer cavity sealing article having more than two layers.

While it is possible that all of the sealing layers of a particular multiple-layer cavity sealing article may be the same, it is also possible that not all of the sealing layers must be the same.

The use of a cavity sealing article in which each sealing layer is the same offers advantages in manufacture, both because only one type of sealing layer is required to be manufactured and because the assembly of the multiple-layer cavity sealing article is simplified when only one type of sealing layer is used — the sealing layer parts of the article are identical and no choice among different parts is required.

However, there may be circumstances in which the use of sealing layers that are not all the same may offer advantages in the multiple-layer cavity-sealing article of this invention. One example is where the cross-section of the cavity to be sealed changes substantially at the predetermined location, such as where the cavity changes in cross-sectional area, where the cavity changes in cross-sectional shape but not in area, or where the cavity curves or is otherwise irregular at the predetermined location. In each of these circumstances, it will be apparent to a person of ordinary skill in the art that it may be desirable that the sealing layers be of different sizes and/or shapes even if they are otherwise identical in composition and thickness, so that each sealing layer may be chosen to best seal the cross-section of the cavity at the point where it is placed. Even if

the cross-section of the cavity to be sealed is the same for each sealing layer of a multiple-layer cavity sealing article, it still may be desirable that the sizes, compositions, thicknesses, or degrees of expansion of the various sealing layers not all be the same. For example, it is highly desirable that at least one (and preferably all) of the sealing layers of the article completely seal the cross-section of the cavity at the point where it is placed. If only one sealing layer is used, then, that layer is chosen to ensure complete sealing, and this certainty of sealing (achieved by choice of the driver and sealer size, degree of expansion, etc.) may not in itself be optimal in other properties, such as acoustic properties. In particular, it may require that the sealing layer have a hardness that is greater or less than desirable for maximum acoustic benefit. In the multiple-layer article of this invention, it is possible to have different sealing layers optimized for different functions within the sealing article. For example, one sealing layer may be optimized to ensure complete sealing of the cavity cross-section while another sealing layer may be optimized to provide a more efficient acoustic barrier, etc. Similarly, the sealing layers may be of different thicknesses, if desired. A person of ordinary skill in the art, having regard to that knowledge and this disclosure, will be able to determine suitable sealing layers for a multiple-layer sealing article of this invention and to optimize them for a particular application.

A person of ordinary skill in the art will be able, having regard to that skill and this disclosure, to select suitable materials and perform a suitable method of manufacture for a cavity sealing article or sealing layer(s) of a sealing article of this invention.

<u>The support structure</u>

If the cavity sealing article of this invention comprises a support structure, that support structure performs two functions: first, it is adapted to fit within the cavity to be sealed and orient the article or sealing layer(s) within the cross-section of the cavity at the predetermined location; and second, in the case of a multiple-layer sealing article, it supports the sealing layers in spaced-apart relationship.

The support structure or components may be prepared from any material having the structural integrity and durability necessary to permit storage of the cavity sealing article of this invention, placement of the article within a cavity to be sealed, sealing of

the cavity by foaming of the article, and use of the article within the cavity, potentially for an extended time such as the lifetime of a vehicle. This requires both structural stability at elevated temperatures, such as stability at temperatures of at least 150°C, preferably at temperatures of at least 180°C, and the ability to withstand the forces produced by foaming of the article at those temperatures, and long-term durability Typically, the mounting means may be prepared from metal, such as steel, including metal mesh, especially when used for a support plate such as plate 42 in FIGS. 9 and 10, or may be prepared from a high melting point thermoplastic polymer, such as a high temperature polyolefin, a polyamide such as a nylon, for example, nylon 6, nylon 46, or nylon 66, a polyester, such as polyethylene terephthalate, an aromatic polyether, polyether ketone, or polyamide, a thermoset resin, or the like; especially one that may easily be formed into the desired shape. These polymers will typically contain fillers, antioxidants, flame retardants, and/or other stabilizers such as are conventional in polymeric articles, and may contain pigments, plasticizers, adhesion promoters, and the like. In addition, the polymers may contain reinforcing materials, such as glass fiber and the like, if needed or desired. The support structure may be formed as a single piece, such as by molding, or assembled from two or more pieces.

The shape of the support structure is designed so that it fits within the cavity to orient the article within the cross-section of the cavity at the predetermined location, desirably so that the sealing layer(s) lie perpendicular to the cavity walls, and the support structure will therefore be provided with features that are capable of interaction with the cavity walls to provide that orientation, as is discussed further below.

In addition, the shape of the support structure for a multiple-layer cavity sealing article is designed so that it supports the plurality of sealing layers in spaced-apart relationship. Thus, for each sealing layer, the support structure will provide a support for that layer so that it is appropriately oriented within the cavity and so that a sealed space is formed within the cavity between each two sealing layers when the sealing layers of the article have been foamed and expanded. Typically, the support structure will support the plurality of sealing layers in parallel spaced-apart relationship; but if the cavity is of irregular shape or is to be sealed at a curve, etc., it may be desirable for the sealing layers

to be non-parallel so that each sealing layer separately lies perpendicular to the cavity walls, for example.

Thus, the support structure may comprise one or a plurality of support plates or trays, one for each sealing layer, which are in turn fastened in spaced-apart relationship to one another, and means for locating the support structure in the cavity, such as are well-known in the art for other foamable cavity seals.

The spacing between the or each pair of sealing layers in a multiple-layer article may be chosen to maximize the attenuation at a desired frequency, achieved by spacing the sealing layers approximately $\lambda/4$ apart, where λ is the wavelength of the sound at the desired frequency. Because the sealing layers are not themselves completely rigid, this idealized $\lambda/4$ spacing may not in fact be optimal, and some adjustment of the spacings may be appropriate to achieve the attenuation profile most desired. Such adjustments are within the ordinary skill of the art.

Depending on its design and intended use, the support structure may be made to be emplaced and retained within the cavity to be sealed by any suitable means, such as by fastening to a wall of the cavity by a fastener of some sort such as the bolt and nut illustrated in FIGS. 10 and 12, or by some similar fastening means such as a clip or stud, and/or may be made so that features of the support structure grippingly engage the walls of the cavity to retain the article in the predetermined location, such as by means of the protrusions illustrated in FIGS. 17 through 19.

Manufacture of the supported cavity sealing article

The supported cavity sealing article is manufactured by mounting the or each of the sealing layers on the support structure. Depending on the design of the article, this may be accomplished by mounting the or each sealing layer on the structure by means of one or more studs, screws, or relatively small supports. The sealing layers may also be provided with holes to engage protrusions, clips, or the like, formed in the support structure; or the support structure may be provided with adhesive surfaces by which the sealing layers may be fastened to it.

Because the driver portion of the or each sealing layer of the article of this invention is crosslinked, it does not flow when heated to a temperature above the melting

point of the polymers comprising it, although it will soften to a certain extent (depending on the materials, the extent of cross-linking, and the temperature). It is therefore a particular benefit of the multiple-layer sealing article of this invention that the driver portion of each sealing layer is relatively dimensionally stable and each sealing layer of the article can therefore be emplaced on the support structure by a simple support means such as those described previously, rather than requiring substantial support to prevent its sagging during heating and foaming (especially when the cross-section to be sealed is vertical and sagging of the sealing layer would tend to cause the sealing material to pull away from the cavity wall above the sealing article. As a result, the sealing layers of this invention do not need expensive, complex, or precise mounting on the support structure, but yet will still provide an excellent seal when used.

It will be evident to one of ordinary skill in the art, having regard to that skill and this disclosure that a variety of means may be used to emplace the sealing article of this invention within a cavity to be sealed, and that all such means fall within the scope of this invention.

Use of the cavity sealing article

The cavity sealing article of this invention is used by placement in the cavity to be sealed, preferably approximately centrally in the cavity cross-section and with the cross-section of the article approximately coincident with the cross-section of the cavity. The article may be emplaced in the cavity by such means as are conventional in the art, for example by emplacement through a hole into an already formed cavity or, more usually, by fastening onto one of two or more members which are subsequently fastened together to form the cavity. It is a feature of the cavity sealing article of this invention that, because of the use of the driver and sealer portions of the article to maximize its cavity filling and sealing efficacy, placement of the article in the cavity is not as position-critical as placement of prior art cavity seals. A single-layer article may be emplaced by mounting on a stud, screw, or other relatively small support (such as is shown in the previously-mentioned Soderberg patent and illustrated in FIGS. 1, 2, and 4). In some instances, the cavity to be sealed will have a structural part or parts which will support the cavity sealing article in a desired location, particularly if the article has been molded or

shaped to a predetermined shape for that location and/or is provided with molded-in features (for example, holes or protrusions) to engage those parts. In other instances, the article may be formed with features, such as protrusions extending from the periphery of the article in the plane of the article, such that the protrusions engage the cavity to provide correct placement of the article in the predetermined location. This is shown in FIG. 8, where a single-layer sealing article 20 is provided with protrusions of the sealer 24A through 24D shaped to engage the cavity walls. The article may also be provided with clips or the like, about which it has been molded, to engage holes in the cavity walls; or may be provided with holes to engage protrusions, clips, or the like, formed in or attached to the cavity walls. The article may also be emplaced by fastening to a support structure such as a support plate or tray (or between a pair of such support plates or trays, although it is a feature of the cavity sealing article of this invention that extensive support is not necessary), which is in turn fastened to or otherwise firmly located in the cavity, such as is well-known in the art for other foamable cavity seals. This is shown in FIGS. 5, 6, 7, 11, and 13, where only one arm 40A of a support bracket is seen; and in more detail in FIGS. 9, 10, 12, and 14, where the support can be seen in more detail.

In FIGS. 9 and 10, a single-layer cavity sealing article 20 is fastened to a support structure comprising a support plate 42, only the periphery of which is visible behind the article, by a bolt 44 passing through a washer 46, a hole in the driver and the support plate and a nut 48. Here, the support plate 42 is mounted on a bracket shown generally at 40, having one arm 40A to which it is fastened and the other arm 40B which is fastened to the cavity wall 14 by a bolt 50 and nut 52, thereby positioning the support plate, and hence the article 20, in the cavity. It will be evident to one of ordinary skill in the art, having regard to that skill and this disclosure that other means may be used to emplace the sealing article of this invention within a cavity to be sealed, and that all such means fall within the scope of this invention.

Because the driver portion of the sealing article of this invention is crosslinked, it does not melt or flow when heated to a temperature above the melting point of the polymers comprising it, although it will soften to a certain extent (depending on the materials, the extent of cross-linking, and the temperature). It is therefore a particular benefit of the sealing article of this invention that the driver portion is relatively

dimensionally stable and the article can therefore be emplaced within the cavity to be sealed by a simple support, rather than requiring substantial support to prevent its sagging during heating and foaming (especially when the cross-section to be sealed is vertical and sagging of the article would tend to cause the sealing material to pull away from the cavity wall above the sealing article, as discussed below in Example 3 and Comparative Example 3). For example, the sealing article may be supported only on a single stud or screw (such as is shown in FIGS. 1, 2, and 4), may be effectively self-supporting (such as is shown in FIG. 8), or may be supported on a support plate with a simple fastener such as a nut and bolt (such as is shown in FIGS. 9, 10, 11, and 12) or a grommet (such as is shown in FIGS. 13 and 14). What is more, because the driver foams and expands in use, it is not necessary that the mounting of the sealing article, for example on a support plate such as in FIGS. 9 and 10, be a sealed mounting: the driver will expand to seal tightly to any mounting means (like the bolt shown) that is used. As a result, the cavity sealing article of this invention does not need expensive, complex, or precise mounting within the cavity to be sealed, but yet will still provide an excellent seal when used.

To permit the passage of drain hoses, electrical wiring, or the like objects through the cavity sealing article of this invention subsequent to the installation and foaming of the article, the cavity sealing article may be provided with one or more apertures through the article. These aperture(s) are typically provided through the driver(s) of the article, as the driver(s) have more uniform expansion and the size of the aperture after foaming of the article can therefore be more easily predicted. In a first method of providing the aperture, the driver may simply have an aperture cut into it during manufacture. The aperture in the driver is sized such that, on expansion of the driver, and hence of the aperture itself, during foaming of the article, the aperture will enlarge to the ultimately desired size. For example, if the driver has a linear expansion of 200% on foaming and the size and shape of the article is such that the expansion of the driver will be unconstrained by the sealer and the cavity walls, and an aperture of 1 cm diameter is desired in the finished seal, an aperture of 5 mm diameter will be provided in the driver when the sealing article is manufactured. If the expansion of the driver is expected to be constrained, then the aperture will be sized accordingly. This aperture may be provided in the driver by any suitable method, such as cutting or molding, and a particularly

convenient method is the simple cutting of the aperture through the driver with a tubular punch of the appropriate size. The material punched out from the driver may be removed before the seal is installed and foamed, or it may be left in place during installation and foaming to provide a "knock-out" aperture which may be opened only if desired, thereby leaving the seal uncompromised if a drain hose or other object is not to be installed. FIG. 11 shows a single-layer cavity sealing article of this invention where an aperture 54 has been provided through the driver 22 of the sealing layer of the article 20. In this embodiment, the arm 40A of the bracket on which the sealing layer of the article 20 is mounted within the cavity is offset from the center of the article, as seen in more detail in FIG. 12, where it maybe seen that the other arm 40B is fastened to the cavity wall. In a second method of providing the aperture, a solid grommet is inserted through the driver during manufacturing of the sealing article. The grommet is of the desired final size and shape of the aperture, and may be provided with means, such as an O-ring, for tightly sealing to a drain hose or like object inserted through the grommet. Typically, if a solid grommet is to be used, it will be attached to a support that is used to retain the cavity sealing article in the predetermined location in the cavity. This is illustrated in FIGS. 13 and 14, where the grommet 56 holds the cavity sealing article 20, through an aperture in the driver 22, to one arm 40A of a bracket 40, of which the other arm 40B is fastened to the cavity wall. In this instance, because the grommet provides a definite size and shape for the aperture, the configuration of the article or sealing layer will desirably be chosen so that the driver expands tightly within the grommet on foaming and expansion of the article. In particular, it may be desirable that the size of the article or sealing layer and its expansion properties be chosen so that expansion of the article on foaming is constrained by the cavity walls, so that the aperture within the driver through which the grommet passes does not expand unconstrainedly away from the grommet.

FIG. 13 is a cross-sectional view showing a ninth, multiple-layer, embodiment of the cavity sealing article of this invention emplaced within a cavity, the longitudinal axis of which is within the page. The multiple-layer cavity sealing article shown generally as 200 comprises two sealing layers shown generally as 200A and 200B supported in spaced-apart relationship by the support structure shown generally as 300. Sealing layer 200A comprises a crosslinked foamable polymer driver 220A surrounded by and in

intimate contact with an uncrosslinked foamable polymer sealer 240A; and sealing layer 200B likewise comprises driver 220B and sealer 240B. Support structure 300 comprises a generally U-shaped strap 320, the center portion of which is secured to the inner side of the cavity wall 120 by a bolt 340 and nut 360; with the two arms of the U projecting into the cavity. Each sealing layer 200A and 200B is further supported by a support plate 380A and 380B respectively, and is fastened to that support plate and to the U-shaped strap 320 by bolts and nuts 400A and 420A and 400B and 420B respectively.

FIG. 14 is a cross-sectional view showing a tenth, multiple-layer, embodiment of the cavity sealing article of this invention emplaced within a cavity, the longitudinal axis of which is within the page, illustrating a different manner of fastening the two sealing layers 200A and 200B to the support structure 300. In this Figure, sealing layer 200A is fastened to the U-shaped strap 320 by an adhesive layer 440; and sealing layer 200B is fastened to the U-shaped strap 320 by two expanding anchors 460A and 460B passing through holes in the strap 320 and the sealing layer 200B. Support plates may also be present, if desired, but are not shown in this Figure.

FIGS. 17 through 19 illustrate an eleventh, multiple-layer, embodiment of the cavity sealing article of this invention, using an alternative support structure. In these three figures, the driver and sealer portions of the sealing layers, and the means holding the sealing layers to the support structure, are not individually shown or described, since their location and function will be evident from the previous figures.

FIG. 17 is a perspective view of this eleventh embodiment, showing sealing layers 200A and 200B supported by the support structure shown generally as 500. The support structure 500 comprises support plates 520A and 520B for sealing layers 200A and 200B, and spacers 540 and 560 maintaining the support plates in spaced-apart relationship. In this embodiment, support plate 520A is shown as having flexible protrusions 580A, 600A, 620A, and 640A; and support plate 520B is shown as having flexible protrusions 580B, 600B, 620B, and 640B. These flexible protrusions are designed so as to grippingly engage the wall of the cavity to be sealed, as better illustrated in FIG. 18, and thereby retain the sealing article in the location within the cavity desired to be sealed.

FIG. 18 is a cross-sectional view of the eleventh embodiment of the multiple-layer sealing article, with the longitudinal axis of the cavity within the page. As can be seen,

the flexible protrusions 580A through 640B of the support structure engage the cavity wall 120 to retain the sealing article in the appropriate position.

FIG. 19 is a cross-sectional view showing the eleventh embodiment of the sealing article after foaming and expansion. Sealing layers 200A and 200B have foamed and expanded to fill the cross-section of the cavity, thereby creating two seals with a "dead space" between them.

It will be apparent that embodiments of the cavity sealing article having multiple sealing layers, such as those shown in FIGS. 15 through 19, may employ sealing layers comprising more than one driver, such as those shown in FIGS. 5, 6, and 7 and described previously with regard to embodiments having a single sealing layer, and/or may be provided with an aperture or apertures therethrough, such as those shown in FIGS. 11 through 14 and described previously with regard to embodiments having a single sealing layer; and all such variations are considered as being within the scope of this invention.

When the article is emplaced within a cavity of a vehicle, the article is desirably placed such that there is substantially complete clearance around it within the cavity before activation and foaming, thereby permitting the phosphating, rustproofing, electrochemical painting, and other treatments such as are commonly given to vehicle bodies. When the article is emplaced within a cavity that is not subject to painting and the like, such clearance is not necessary.

When it is desired to activate and foam the sealing article of this invention, the article is exposed to a sufficient temperature for a sufficient time to activate the blowing agent and the chemical crosslinking agent. Suitable times and temperatures will depend on the application in which the seal is to be used, and may include temperatures between 100°C and 300°C or greater for periods between 5 and 100 minutes. Typically, in the case of sealing channels in new vehicle bodies, this heat activation will occur when the body is placed in a paint bake oven to cure previously applied paint, and such temperatures and times are typically between 115°C and 250°C for 10 to 40 minutes, for example 160°C for 25 minutes, but a person of ordinary skill in the art will realize that other temperatures and times may be appropriate. Also, the sealing article may be activated by other heat sources (for example, local heating such as induction heating of the area), for example if it is being used for repair purposes or is being emplaced in a

large structure. On heating, the uncrosslinked sealer of the article softens and foams while the crosslinked driver(s) of the article foam in a uniform fashion to push the sealer into intimate sealing contact with the walls of the cavity. The foam of the sealer then chemically crosslinks, stabilizing the sealer foam so that the foamed article forms a stable plug filling the whole cross-section of the cavity and intimately bonded to the cavity walls, acting as a moisture, sound, and particulate barrier.

The invention is illustrated by the following Examples and Comparative Examples.

EXAMPLE 1

A foamable sheet was prepared from the following formulation:

Ingredient	Parts by weight
Evatane 28-05 (EVA, 28% VA, MFI 5, Atochem)	100.0
Irganox 1076 (antioxidant, Ciba-Geigy)	2.0
Kadox 911 (zinc oxide)	30.0
Varox 231 XL (peroxide crosslinker, Vanderbilt)	1.5
Celogen TSH (blowing agent, Uniroyal)	10.0
Sartomer 350 (radiation crosslinking promoter, Sartomer)	5.0

A Brabender mixer was set at 80°C; and the Evatane, Irganox, and Kadox were added and blended to homogeneity. The Varox, Celogen, and Sartomer were then added and blended to homogeneity, ensuring that the temperature of the mixer remained below 80°C during the mixing process. The mixed material was then molded, at about 100°C (below the decomposition temperature of the Varox and Celogen), into a sheet of approximately 6 mm thickness.

A test cavity was formed from a section of metal rain-gutter, of irregular but approximately trapezoidal cross-section, approximately 105 mm on the longer of the parallel sides (across the top of the gutter, which was closed with a piece of sheet metal), 70 mm across the shorter of the parallel sides (the bottom), and 75 mm high. The interior

of the test cavity was sprayed with light oil (WD-40®) to simulate contamination of the cavity and provide a more stringent test of the sealing power of the cavity sealing article.

A piece of the foamable sheet prepared as described above was cut to approximately the shape of the test cavity, with linear dimensions approximately 65%-85% of those of the cavity. The piece was a trapezoid, with the longer of the parallel sides being 90 mm, the shorter being 47 mm, and the height being 51 mm. The piece was held in an acrylate jig, with an acrylate mask of approximately 13 mm thickness placed on top of the piece, masking an approximately 13 mm wide strip (forming the sealer portion of the cavity sealing article) around the edge of the piece and leaving an exposed area also of trapezoidal shape, with the longer of the parallel sides being 45 mm, the shorter being 29 mm, and the height being 25 mm, forming the driver portion. The resulting assembly was irradiated with 1.6 Mrad of 3.0 MeV electrons to crosslink the exposed section of the piece (the driver), thereby producing a cavity sealing article of this invention.

The test cavity was placed on a metal sheet so that its axis was vertical and cross-section horizontal, and the cavity sealing article was placed on the metal sheet, in approximately the center of the cavity. The resulting assembly was placed in a 157°C oven for 25 minutes, then removed and allowed to cool.

Examination of the test cavity revealed that the crosslinked driver portion of the article had foamed and expanded isotropically, forming a uniform foam with small closed cells. This foam had forced the uncrosslinked sealer portion at the periphery of the article into close proximity with the walls of the test cavity. The sealer of the article had also foamed, although in a less uniform fashion and with open cells visible on the surface, but, with the driver, had completely filled the test cavity cross-section and displayed excellent adhesion to the cavity walls.

The resulting foamed article was non-tacky and non-moisture absorbing, and effectively sealed the cavity.

Square test pieces of the material of the sealing article of this Example, either crosslinked (like the driver) or uncrosslinked (like the sealer), were foamed for an identical temperature and time, laid horizontally on a metal sheet but not otherwise externally confined. The crosslinked material expanded isotropically with a linear expansion of 200% in each direction (volume expansion of 800%), giving a uniform foam

of small cell size. The uncrosslinked material expanded anisotropically with a linear expansion of approximately 180% in the two horizontal directions and non-uniform vertical expansion of approximately 265% in the center and 100% at the edges (volume expansion of approximately 600%), giving a coarse cell structure.

COMPARATIVE EXAMPLE 1

Cavity sealing articles not of this invention but similar to that of Example 1 were prepared as follows:

without a radiation crosslinking promoter or crosslinking (i.e. lacking a driver); and

with the same formulation as in Example 1, but radiation crosslinked uniformly across its entire area (i.e. lacking a sealer).

These articles were tested in the same manner as the cavity sealing article of Example 1, i.e. placing them horizontally in a test cavity and foaming them in an oven. The non-crosslinked article foamed preferentially in the vertical direction, probably due to adhesion to its support, and did not fill the cross-section of the test cavity; however, adhesion of the foam to the cavity walls was good. The uniformly crosslinked article foamed isotropically; however, it did not adhere to the cavity walls and buckled where it came into contact with them, so that it also did not fill the cross-section of the test cavity.

These results, taken with the results of Example 1, show that a cavity sealing article of this invention with a crosslinked driver and uncrosslinked sealer functions well to seal a cavity, whereas similar articles lacking either the driver or sealer do not function to seal a cavity.

EXAMPLE 2

A cavity sealing article of this invention similar to that used in Example 1 was prepared from a formulation similar to that of Example 1 but containing an additional 30 parts by weight Piccotac 95 (tackifier, Hercules Chemical Co.). The article was tested in the manner described in Example 1. The sealer portion of this article flowed to a greater extent on foaming than the sealer of the article of Example 1; but the article showed the same uniform expansion of the driver, filling of the cavity cross-section, and excellent sealing to the cavity walls that was shown by the article of Example 1.

The resulting foamed article was non-tacky and non-moisture absorbing, and effectively sealed the cavity.

EXAMPLE 3

A cavity sealing article of this invention, and a test cavity, were prepared as in Example 1. The article was adhered by a piece of double-sided adhesive tape to a sheet metal support plate, having a shape and size similar to that of the article, with flanges at the corners of the plate so that the plate (and hence the article) was supported centrally in the cavity. The resulting assembly was placed in the oven with the axis of the cavity horizontal (the article, and the cavity cross-section, therefore being vertical), and was heated at 157°C for 25 minutes to foam the article.

Examination of the test cavity revealed that the crosslinked driver portion of the article had foamed and expanded isotropically, forming a uniform foam with small closed cells. This foam had forced the uncrosslinked sealer portion at the periphery of the article into close proximity with the walls of the test cavity. The sealer of the article had also foamed, although in a less uniform fashion and with open cells visible on the surface, but, with the driver, had completely filled the test cavity cross-section and displayed excellent adhesion to the cavity walls.

The resulting foamed article was non-tacky and non-moisture absorbing, and effectively sealed the cavity.

COMPARATIVE EXAMPLE 3

A cavity sealing article not of this invention but similar to that of Example 1 was prepared by manufacturing the article using the same procedure as in Example 1 but not radiation crosslinking the center area, so that the article lacked a driver. The article was tested in the same manner as the cavity sealing article of Example 3, i.e. placing it vertically in a test cavity and foaming it in an oven. The article foamed preferentially in the horizontal direction, sagged badly away from the upper part of the cavity walls, and did not fill the cross-section of the test cavity; however, adhesion of the foam to the cavity walls was good.

These results, taken with the results of Example 3, show that a cavity sealing article of this invention with a crosslinked driver and uncrosslinked sealer functions well to seal a cavity, whereas a similar article lacking the driver does not function to seal a cavity.

EXAMPLE 4

A test cavity of approximately trapezoidal shape was prepared from mild steel. The base of the trapezoid was 76 mm, the top was 70 mm, and the height was 67 mm. The two top corners of the trapezoid were rounded, and the two base corners were pinch welded, forming sharp vertices.

Cavity sealing articles according to this invention were prepared generally as in Example 1, but with the articles each having a plurality of drivers and a sealer in intimate contact with and substantially surrounding the drivers. A foamable sheet was prepared from the following formulation:

Ingredient	Parts by weight
Elvax 470 (EVA, duPont)	80
Evatane 28-05 (EVA, 28% VA, MFI 5, Atochem)	20
Irganox 1076 (antioxidant, Ciba-Geigy)	2
Kadox 911 (zinc oxide)	10
OMYA-Car-UFT (calcium carbonate)	30
Raven C Ultra Beads (carbon black)	2
Piccotac 95 (tackifier, Hercules)	15
Varox DCP40KE (peroxide crosslinker, Vanderbilt)	4
Celogen OT (blowing agent, Uniroyal)	5
Sartomer 350 (radiation crosslinking promoter, Sartomer)	5

A Brabender mixer was set at 80°C; and all materials except the Varox, Celogen, and Sartomer were added and blended to homogeneity. The Varox, Celogen, and Sartomer were then added and blended to homogeneity, ensuring that the temperature of the mixer remained below 80°C during the mixing process. The mixed material was then

pelletized to give pellets of a base uncrosslinked foamable polymer. Sheets 6.5 mm thick were molded from these pellets at about 100°C (below the decomposition temperature of the Varox and Celogen), and irradiated with 4.8 Mrad of 3.5 MeV electrons in patterned fashion to form articles of this invention.

In one example, the drivers were 3 mm squares, spaced on a square grid on 6 mm centers; in a second, the drivers were 6 mm squares on 12 mm centers; in a third, the drivers were 13 mm squares on 19 mm centers; in a fourth, the drivers were 3 mm diameter circles on 6 mm centers; in a fifth, the drivers were 6 mm diameter circles on 12 mm centers; and in other embodiments, the drivers were of non-uniform shapes. On heating, each of these articles foamed and sealed to the walls of the test cavity.

EXAMPLE 5 (SIMULATED MULTIPLE-LAYER CAVITY SEALING ARTICLE)

To demonstrate the characteristics of the multiple-layer cavity sealing article of this invention, a simulated double-layer cavity sealing article was prepared by mounting two single-layer cavity sealing articles in close proximity within a test channel; and the acoustic characteristics of various simulated double-layer articles so prepared compared with each other and with a single-layer article.

As an example, two sealing layers were prepared by preparing a 60 mm × 60 mm square of 6.4 mm thick foamable polymer, of which the central 40 mm × 40 mm section (the "driver") was radiation cross-linked to have a linear expansion of about 150% (volume expansion of about 340%). Each sealing layer was bolted with a 3 mm bolt through the center of the sealing layer to a 60 mm × 60 mm backplate of 3 mm wire mesh, on the other side of which was a 19 mm wide L-shaped aluminum strap, the longer leg of which was 50 mm long with a first hole 12 mm from the end of the longer leg, the bolt passing through that hole and being secured by a nut; and the shorter leg of which was 25 mm long with a second hole 12 mm from the end of the shorter leg. The strap was secured to the inner wall of a 250 mm long channel made from 0.8 mm steel, having a 75 mm × 75 mm square cross-section, by a bolt through that second hole; so that the sealing layer was positioned centrally in the cross-section of the channel, with the nearer sealing layer to the end of the channel being approximately 50 mm from the end of the channel. The distance between the two sealing layers could be adjusted by placement of

the supports within the channel. Similar sealing layers of different degrees of expansion, sizes, and thicknesses, were also prepared.

Acoustic testing was conducted in the manner described in Saha and Myers, "Evaluating Acoustical Performance of Expandable Sealant Materials", SAE Technical Paper No. 930336, SAE International Congress and Exposition, Detroit, Michigan, March 1-5, 1993. The channel was mounted in a fixture filling an opening located in the wall of a reverberation room containing a loudspeaker and source microphone, with a small anechoic chamber on the other side of the opening containing a receiving microphone. The insertion loss (in effect, the attenuation caused by the sealing article) was measured over the range 125 Hz - 10 KHz.

A single layer sealing article of 12.7 mm thickness, tested for comparative purposes, using a medium expansion (160% linear expansion) foam of the type described in Example 1 showed an insertion loss (the difference between the receiving microphone sound pressure levels before and after insertion of the cavity sealing article, measured in decibels) of 10 - 12 dB between 125 and 200 Hz, rising to about 50 dB at 500 Hz, then dipping to about 30 dB at 800 Hz, rising again to 45 dB by 1600 Hz, then staying in the range of 40 - 45 dB until 10 KHz. Similar single layer sealing articles of 9.5 mm and 6.4 mm thickness showed similar performance below 500 Hz, a drop to about 20 dB between 800 and 1250 Hz, and an insertion loss in the 2 KHz to 10 KHz range that averaged 35 - 40 dB.

A double-layer sealing article of this invention, using two 6.4 mm thickness sealing layers of the same foam spaced 38 mm apart, showed comparable attenuation up to 500 Hz, no significant drop around 1 KHz, and an insertion loss averaging better than 6 dB greater than that of the 12.7 mm single layer sealing article in the 2.5 KHz - 10 KHz range, with the difference increasing with increasing frequency.

A similar result was seen for high expansion (200% linear expansion) foams, where the drop in insertion loss for the single-layer article near 1 KHz was even greater than for the medium expansion foam and was absent for the double-layer article, but the difference in high-frequency insertion loss was not quite as great. Typically, greater expansion, which results in a softer foam, gives better high frequency attenuation for both single-layer and double-layer articles.

These data indicate that for the same total thickness of sealing layer, a double-layer cavity sealing article provides better acoustic performance (greater attenuation) than a similar single-layer cavity sealing article.

Varying the spacing between the sealing layers of a double-layer article using medium expansion foam from 25 mm to 38 mm had little effect on the insertion loss, though the greater spacing provided slightly greater and more even attenuation.

In a test using double-layer articles with sealing layers of different expansion (hardness), it was found that the combination of one low expansion (125% linear expansion), relatively hard sealing layer and one high expansion (200% linear expansion, relatively soft sealing layer gave slightly greater insertion loss than was achieved with the same design using two identical high expansion sealing layers.

These data indicate that varying the spacing between the sealing layers, and using non-identical layers, in the multiple-layer cavity sealing article of this invention enables variation in the characteristics of the sealing article.

While this invention has been described in conjunction with specific embodiments and examples, it will be evident to one of ordinary skill in the art, having regard to this disclosure, that equivalents of the specifically disclosed materials and techniques will also be applicable to this invention; and such equivalents are intended to be included within the following claims.

CLAIMS

1. A planar cavity sealing article comprising:

(a) at least one driver comprising a crosslinked foamable polymer, and

(b) a sealer comprising an uncrosslinked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the article.

2. A planar cavity sealing article for use in a longitudinally extending cavity defined by cavity walls, the cavity having a cross-section within the cavity walls which is to be sealed at a predetermined location, the article comprising:

(a) at least one driver comprising a crosslinked foamable polymer, and

(b) a sealer comprising an uncrosslinked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the article;

the article having a size and shape such that the article incompletely occupies the cross-section of the cavity at the predetermined location and having expansion and sealing properties such that, when the article is placed at the predetermined location within the cavity and foamed, the foamed sealer is forced into intimate and sealing contact with the cavity walls.

3. A cavity sealing article for use in a longitudinally extending cavity defined by cavity walls, the cavity having a cross-section within the cavity walls which is to be sealed at a predetermined location, the article comprising:

(a) a planar cavity sealing layer comprising:

  (1) at least one driver comprising a crosslinked foamable polymer, and

  (2) a sealer comprising an uncrosslinked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the layer; and

(b) a support structure adapted to fit within the cavity and orient the article within the cross-section at the predetermined location,

the article having a size and shape such that the article incompletely occupies the cross-section of the cavity at the predetermined location and the sealing layer having expansion and sealing properties such that, when the article is placed at the predetermined location within the cavity and foamed, the foamed sealer is forced into intimate and sealing contact with the cavity walls.

4. A multiple-layer cavity sealing article comprising:

(a) a plurality of planar sealing layers, each sealing layer independently comprising:

  (a) at least one driver comprising a crosslinked foamable polymer, and

  (b) a sealer comprising an uncrosslinked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the layer; and

(b) a support structure supporting the plurality of sealing layers in spaced-apart relationship.

5. A multiple-layer cavity sealing article for use in a longitudinally extending cavity defined by cavity walls, the cavity having a cross-section within the cavity walls which is to be sealed at a predetermined location, the article comprising:

(a) a plurality of planar sealing layers, each sealing layer independently comprising:

  (a) at least one driver comprising a crosslinked foamable polymer, and

  (b) a sealer comprising an uncrosslinked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the layer; and

(b) a support structure adapted to fit within the cavity and orient the article within the cross-section at the predetermined location, the support structure supporting the plurality of sealing layers in spaced-apart relationship,

the article having a size and shape such that the article incompletely occupies the cross-section of the cavity at the predetermined location and the sealing layers having expansion and sealing properties such that, when the article is placed at the predetermined location within the cavity and foamed, the foamed sealers are forced into intimate and sealing contact with the cavity walls.

6. The article of Claims 4 or 5 which comprises two sealing layers.

7. The article of Claims 4 through 6 where each sealing layer is the same.

8. The article of any one of Claims 1 through 7 where the article or the or each sealing layer of the article has only one driver.

9. The article of any one of Claims 1 through 7 where the article or the or each sealing layer of the article has more than one driver.

10. The article of any one of Claims 1 through 9 where, in the article or in the or each sealing layer of the article, the foamable polymer of the at least one driver and of the sealer are the same.

11. The article of Claim 10 where the foamable polymer of the at least one driver is a radiation crosslinked foamable polymer.

12. The article of Claim 11 where the at least one driver and the sealer are formed from a single piece of foamable polymer that has been selectively irradiated to form the driver.

13. The article of any one of Claims 1 through 12 where the article or the or each sealing layer of the article has a thickness between 3 mm and 13 mm.

14. The article of Claim 13 where the article or the or each sealing layer of the article has a thickness between 5 mm and 8 mm.

15. The article of any one of Claims 2, 3, and 5 through 14 where the article or the or each sealing layer of the article has a cross-sectional shape corresponding generally to the cross-section of the cavity at the predetermined location.

16. The article of any one of Claims 1 through 15 having at least one aperture therethrough.

17. A method of sealing a longitudinally extending cavity defined by cavity walls, the cavity having a cross-section within the cavity walls which is to be sealed at a predetermined location, the method comprising:

(a) providing a planar cavity sealing article according to any one of Claims 1 through 16;

(b) placing the article within the cross-section of the cavity at the predetermined location; and

(c) heating the article for a sufficient time and to a sufficient temperature that the article or the or each sealing layer foams to form an expanded foam barrier in the cross-section of the cavity and seals to the cavity walls.

18. The method of Claim 17 where the cavity is a cavity within a unibody frame of an automobile, and the step of heating comprises baking the frame of the automobile in a paint bake oven.

19. A method of preparing a planar cavity sealing article or a sealing layer for a cavity sealing article comprising at least one driver comprising a crosslinked foamable polymer and a sealer comprising an uncrosslinked foamable polymer in intimate contact with the at least one driver and substantially surrounding the at least one driver in the plane of the article or layer, the method comprising:

(a) providing a foamable polymer sheet; and

(b) selectively crosslinking that portion or portions of the sheet which is to become the at least one driver of the article.

20. The method of claim 19 where the step of selective crosslinking is performed by selective irradiation of the portion or portions with ionizing radiation.

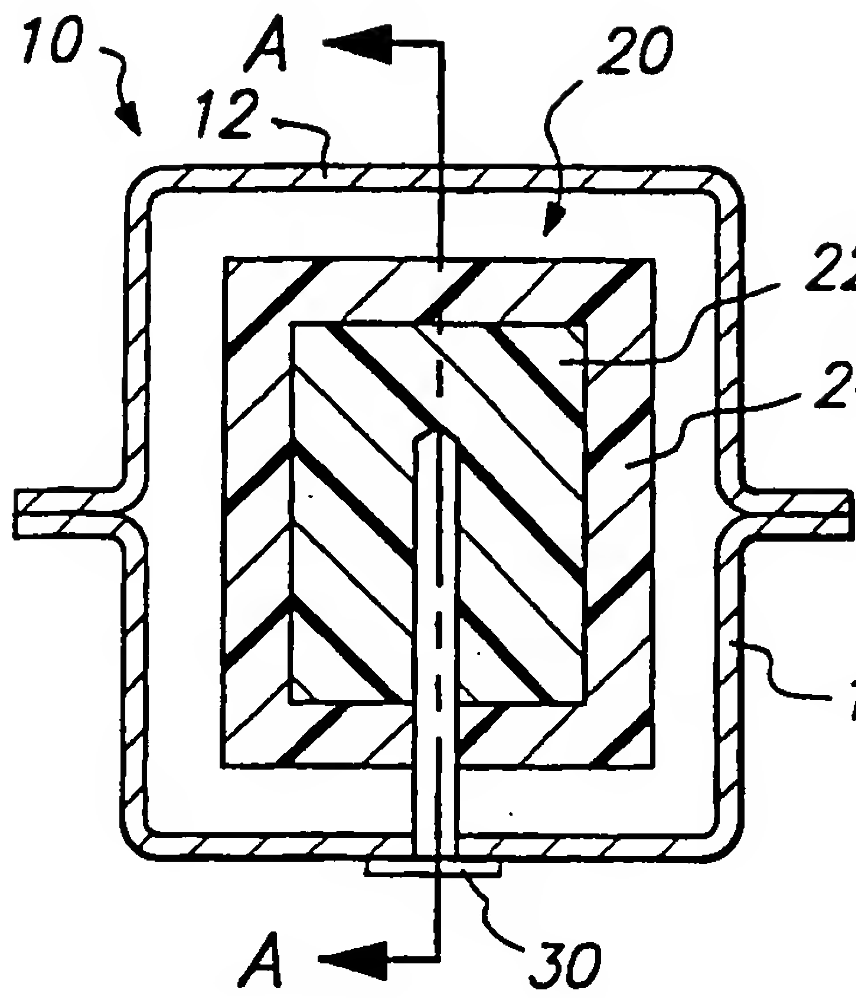

FIG. 1

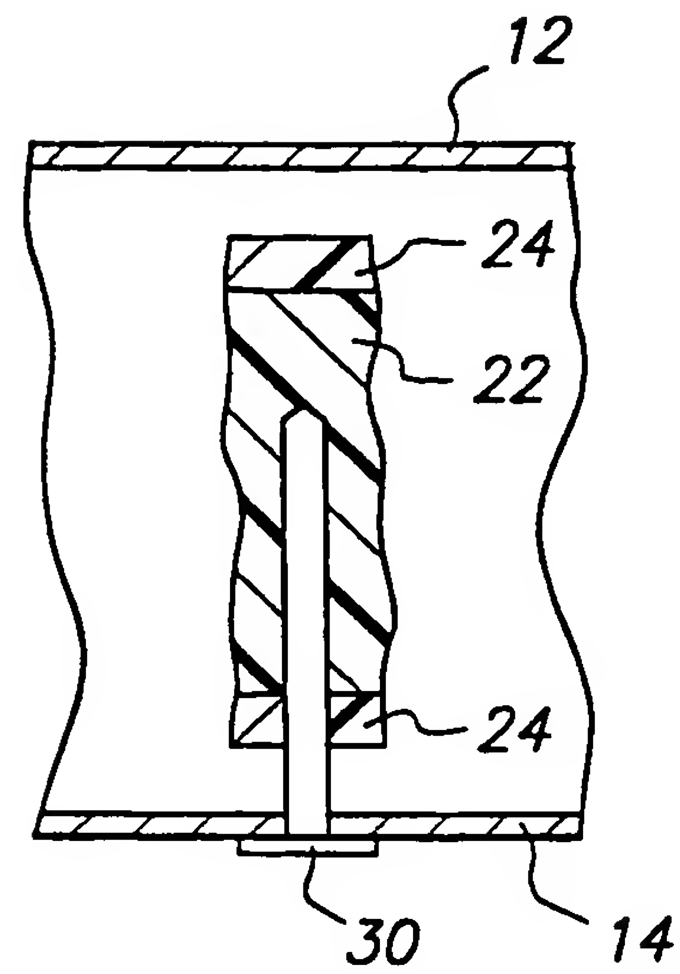

FIG. 2

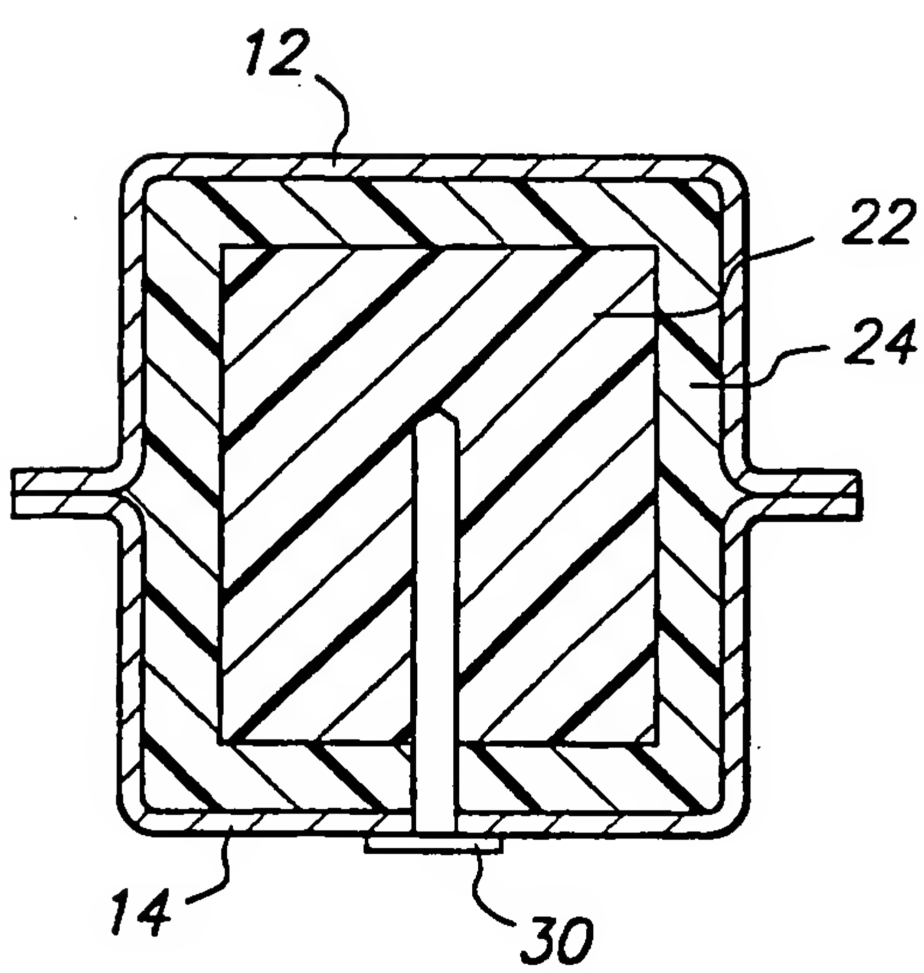

FIG. 3

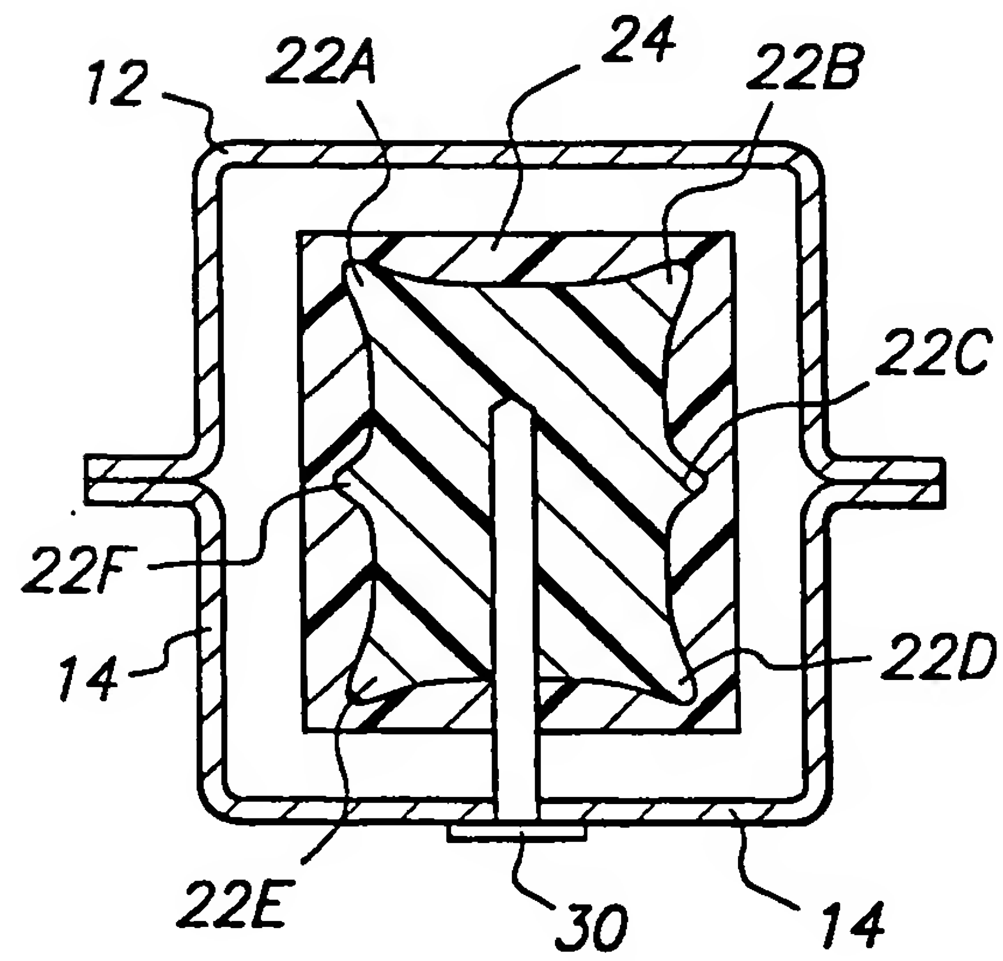

FIG. 4

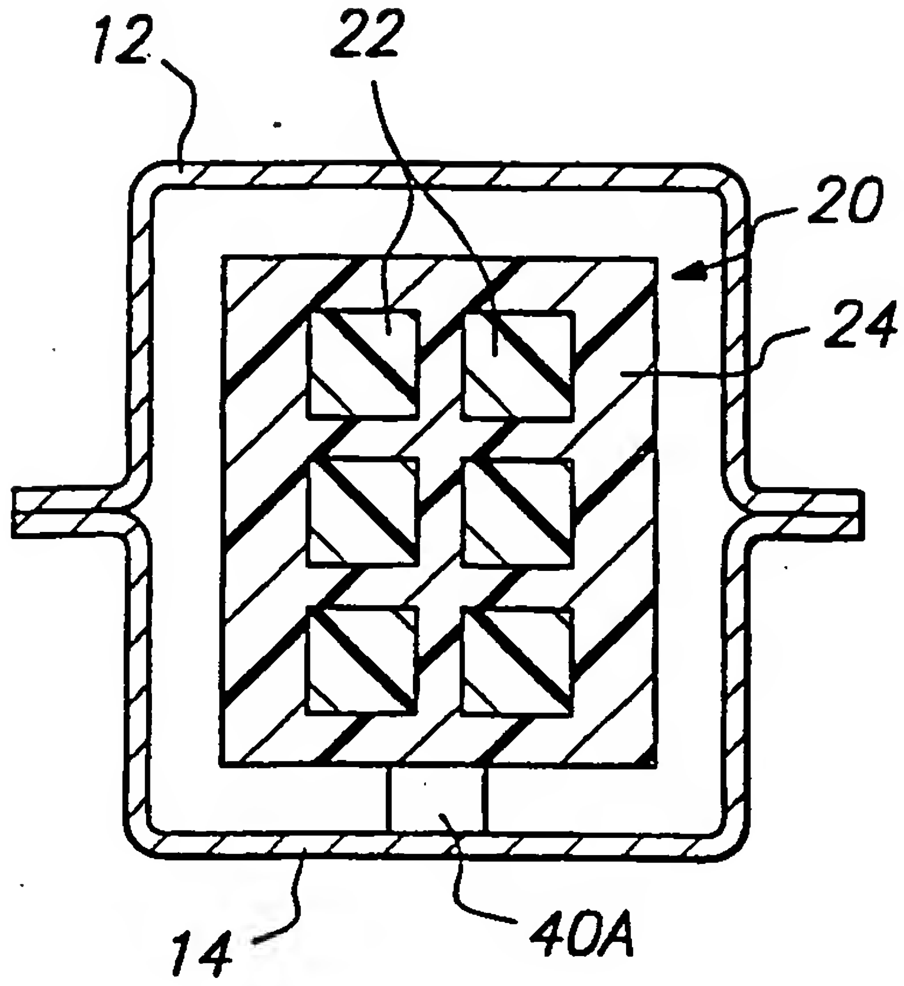

FIG. 5

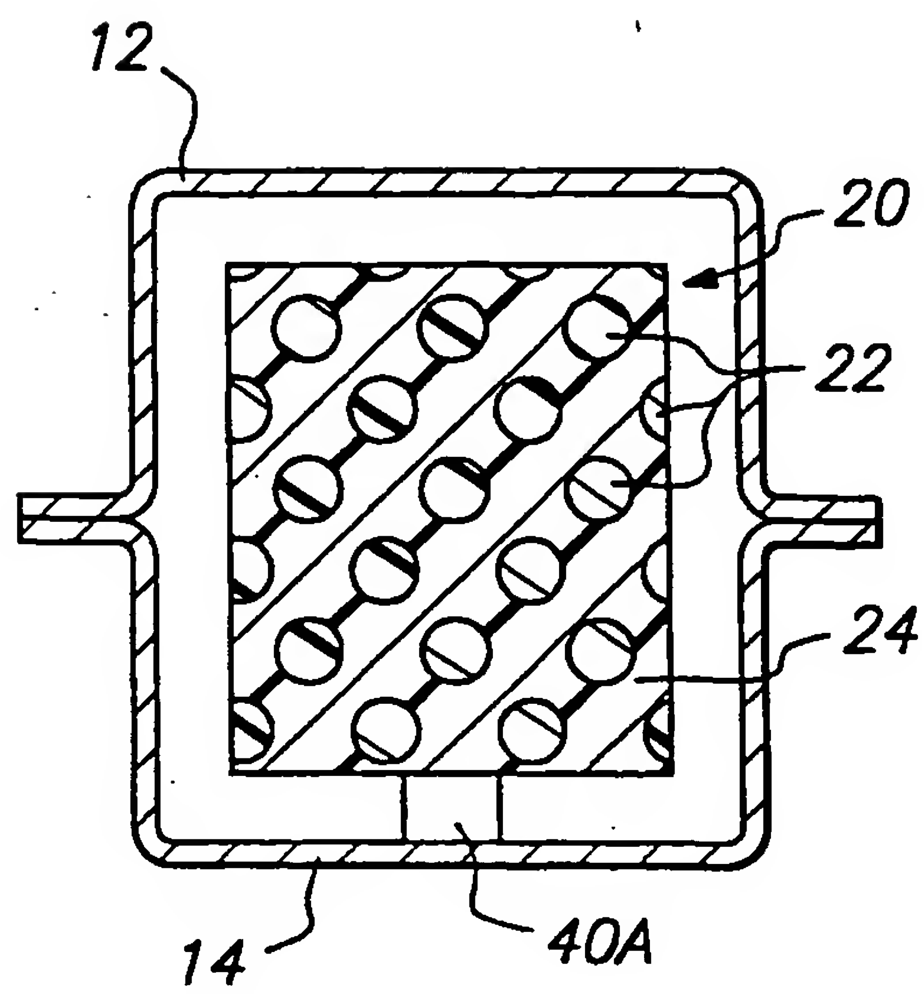

FIG. 6

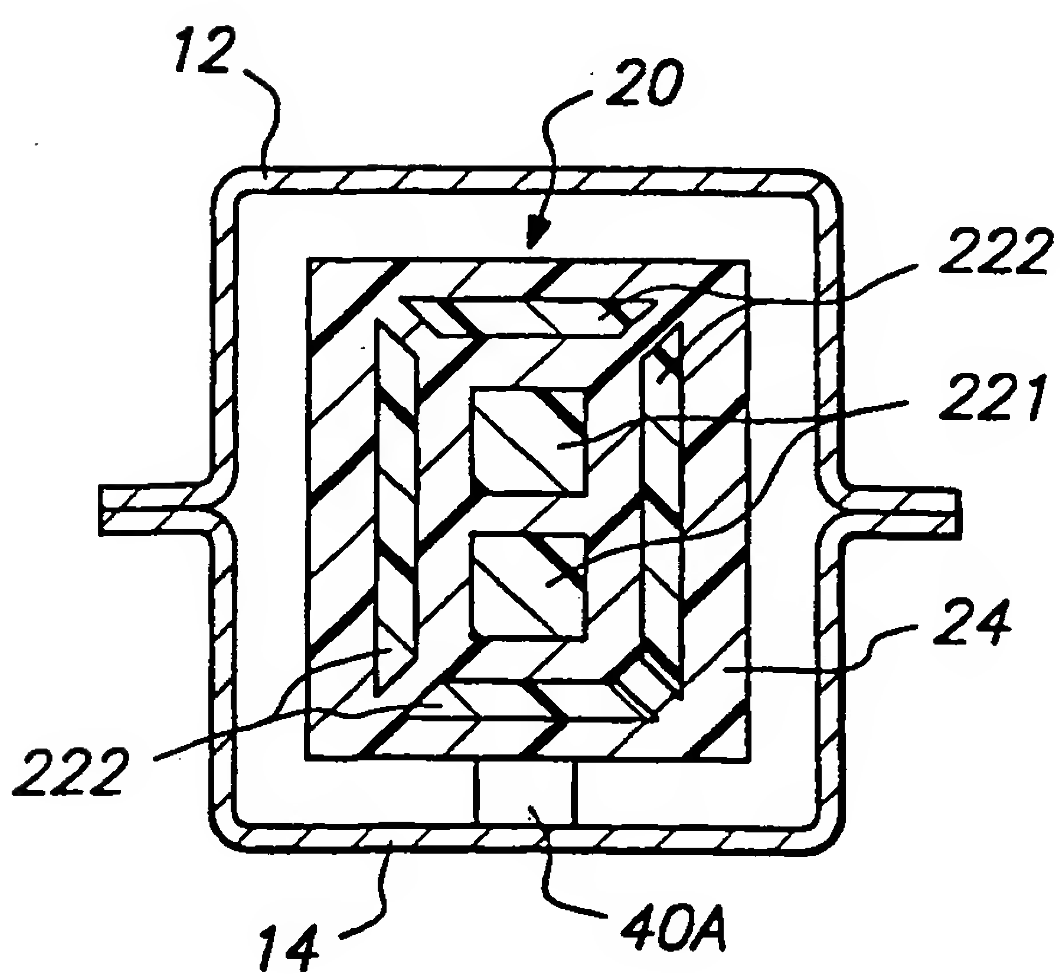

FIG. 7

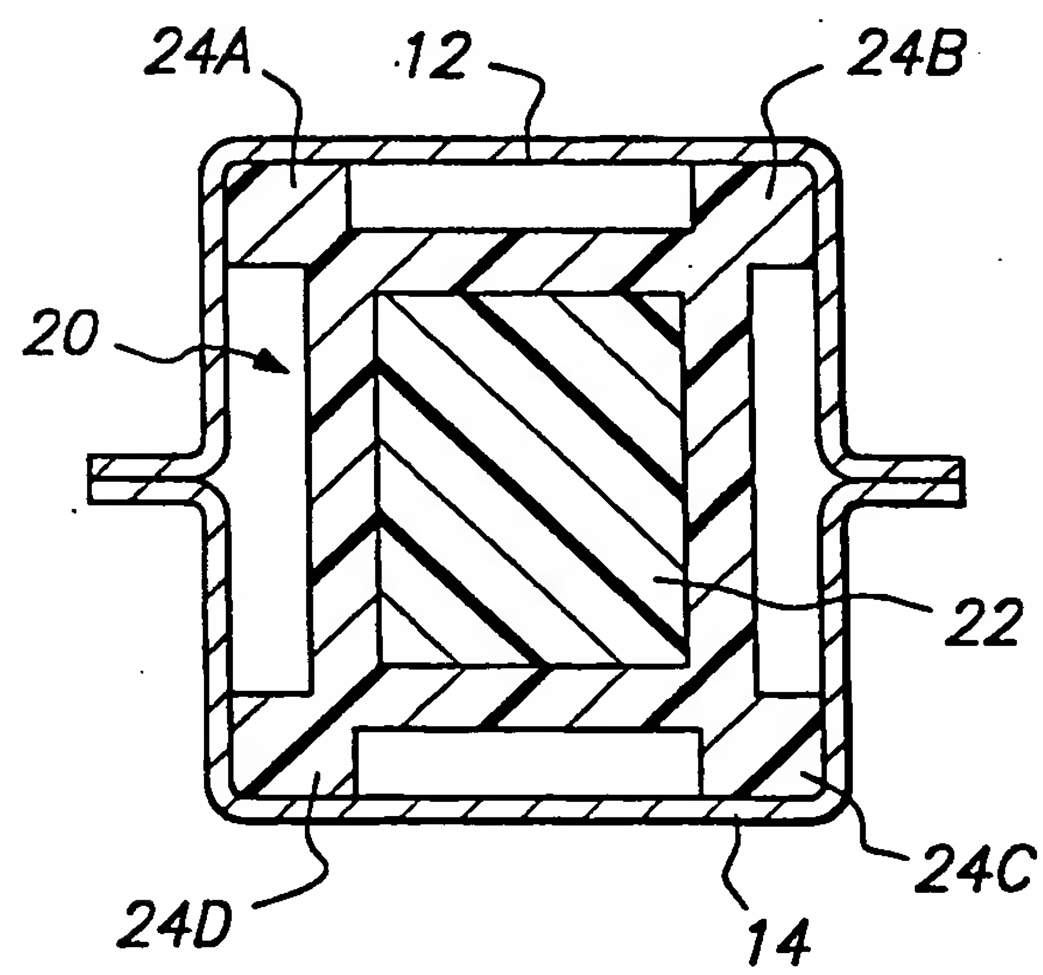

FIG. 8

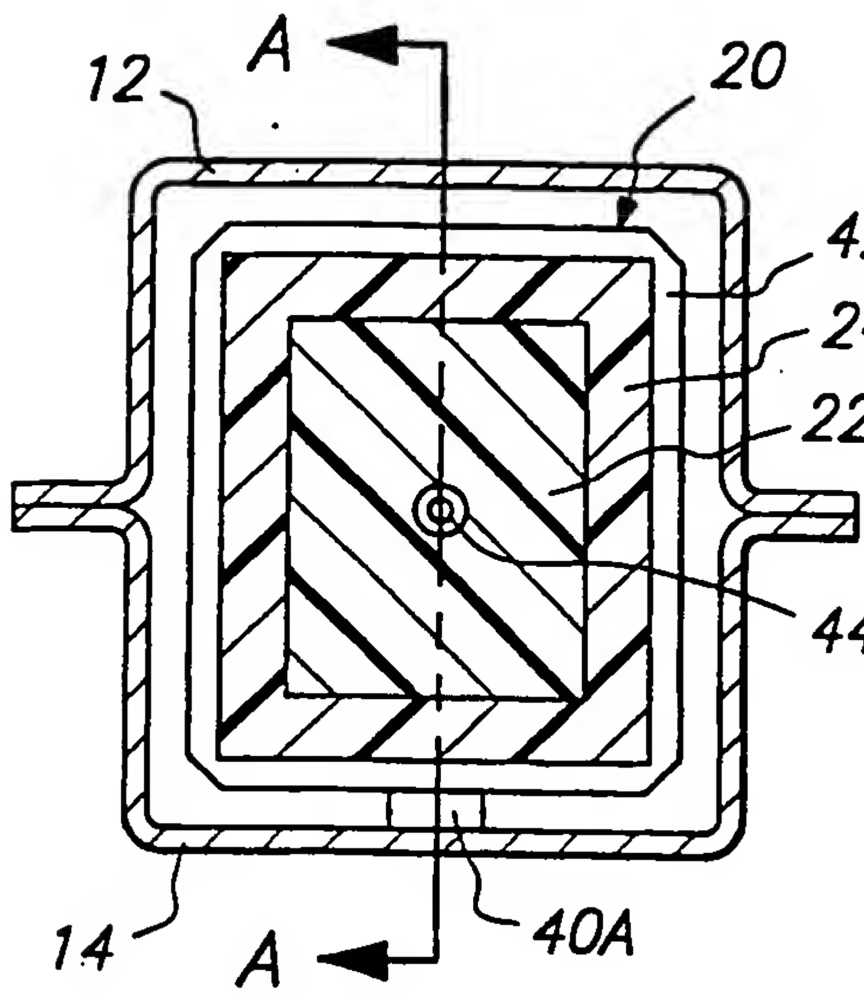

FIG. 9

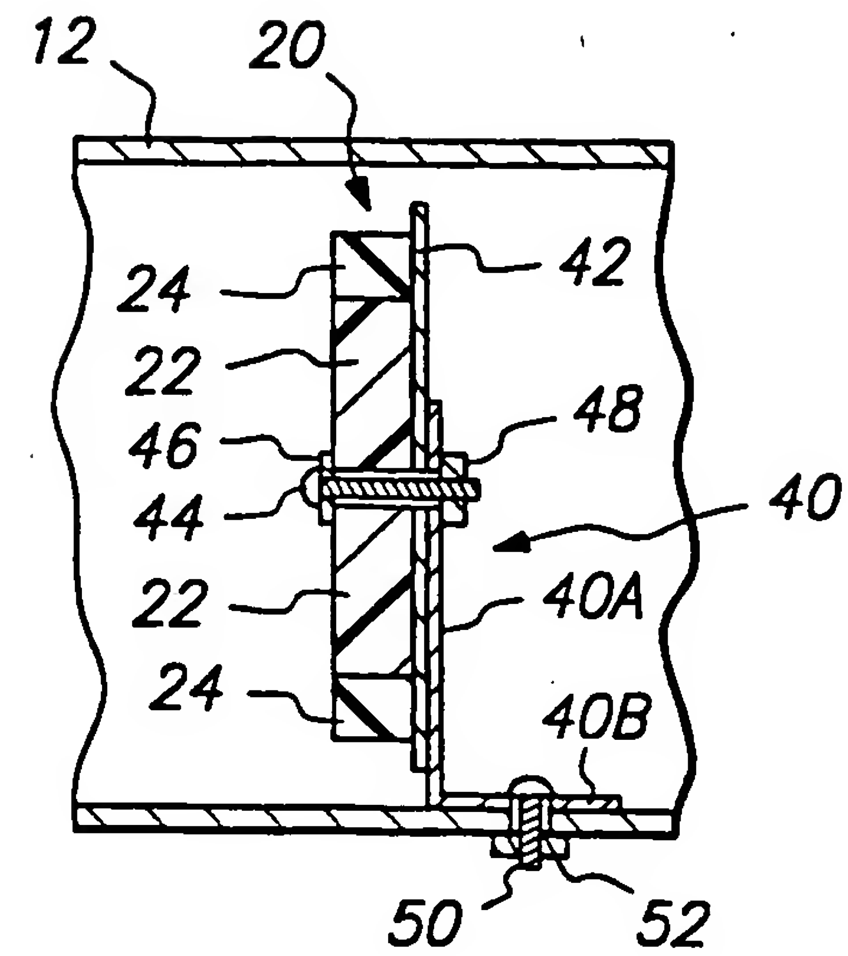

FIG. 10

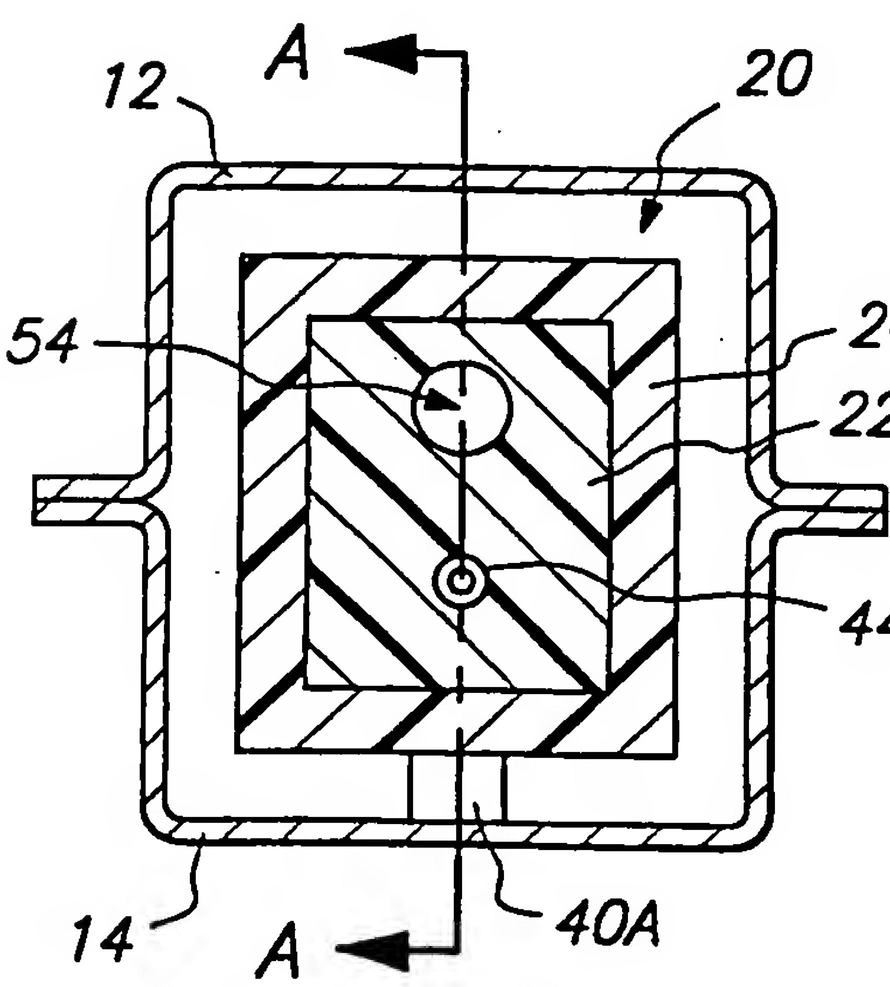

FIG. 11

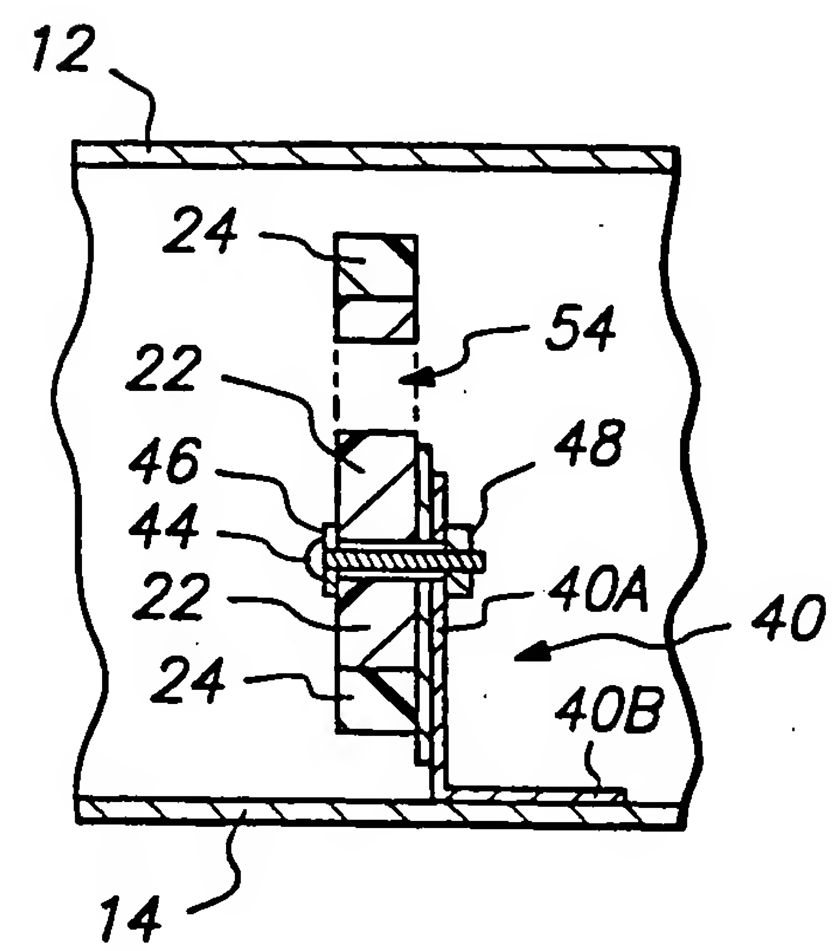

FIG. 12

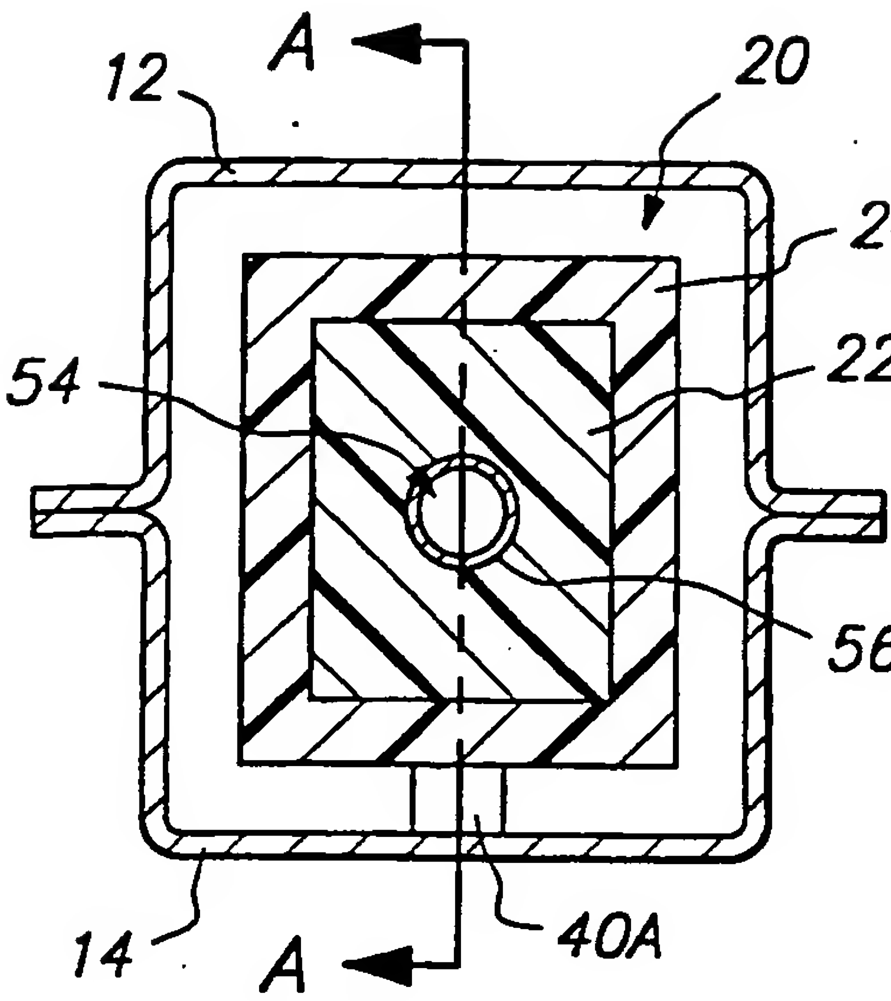

FIG. 13

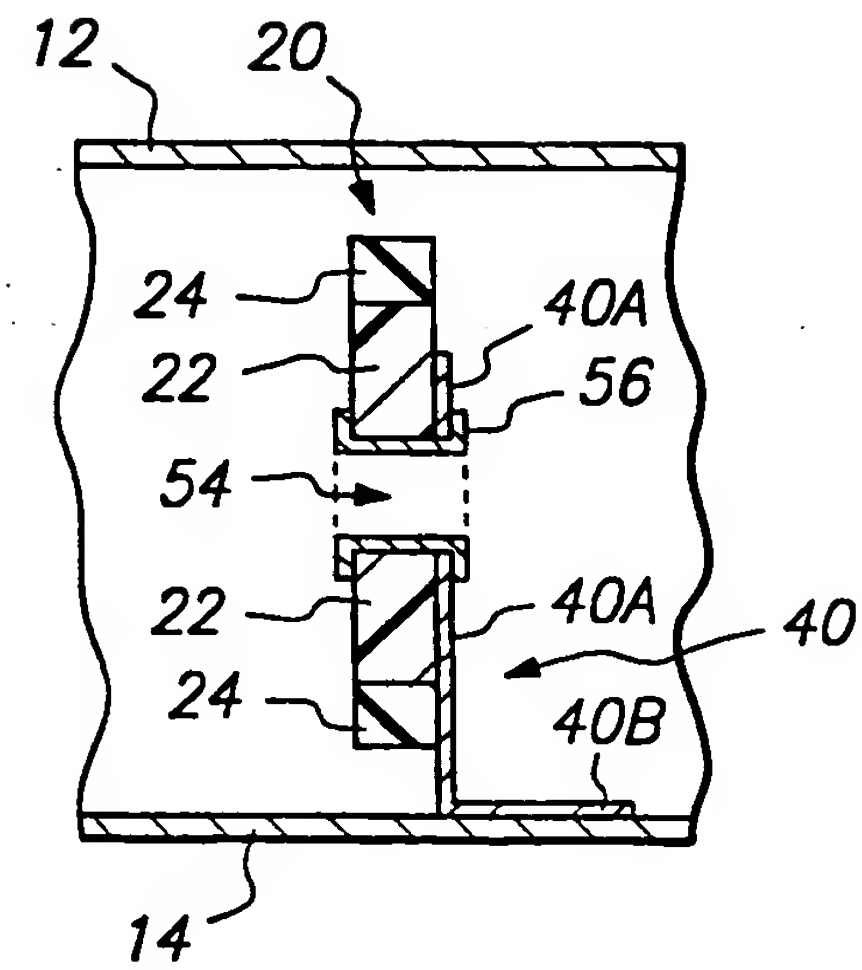

FIG. 14

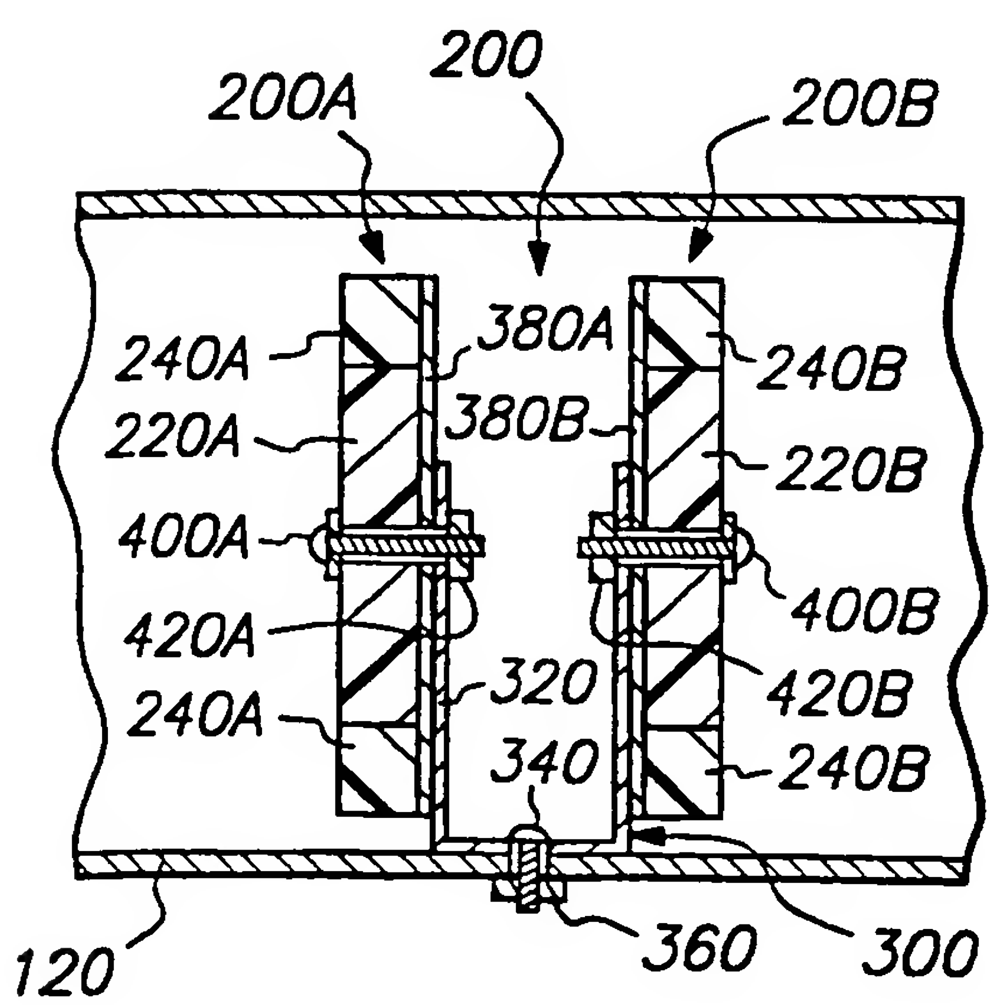

FIG. 15

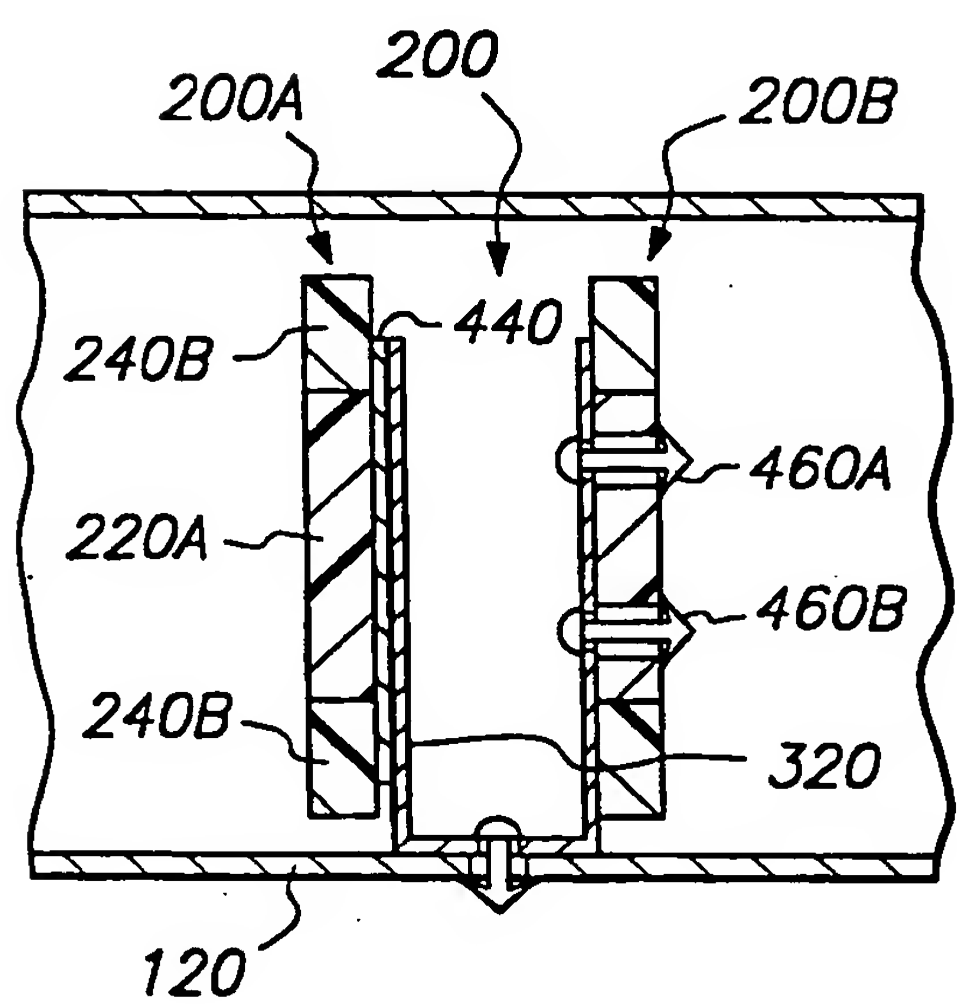

FIG. 16

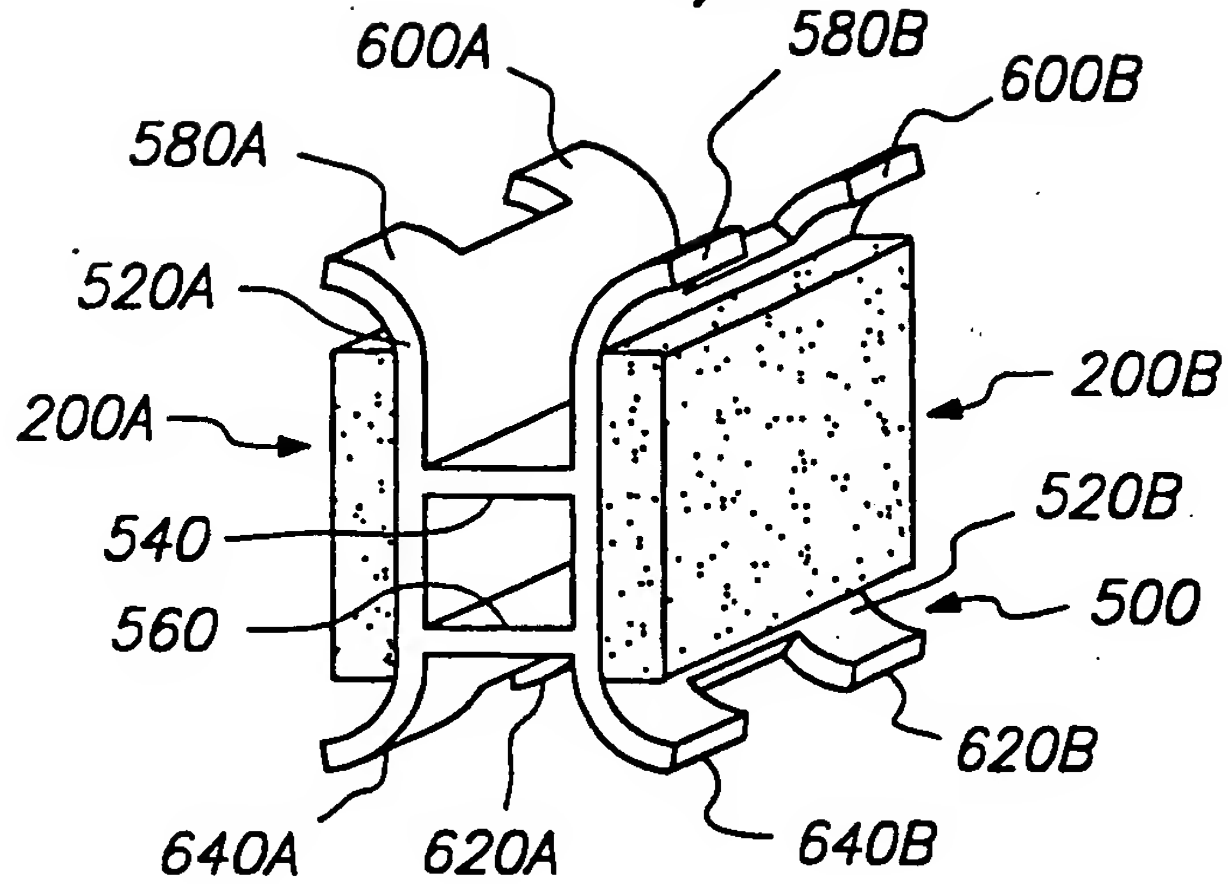

FIG. 17

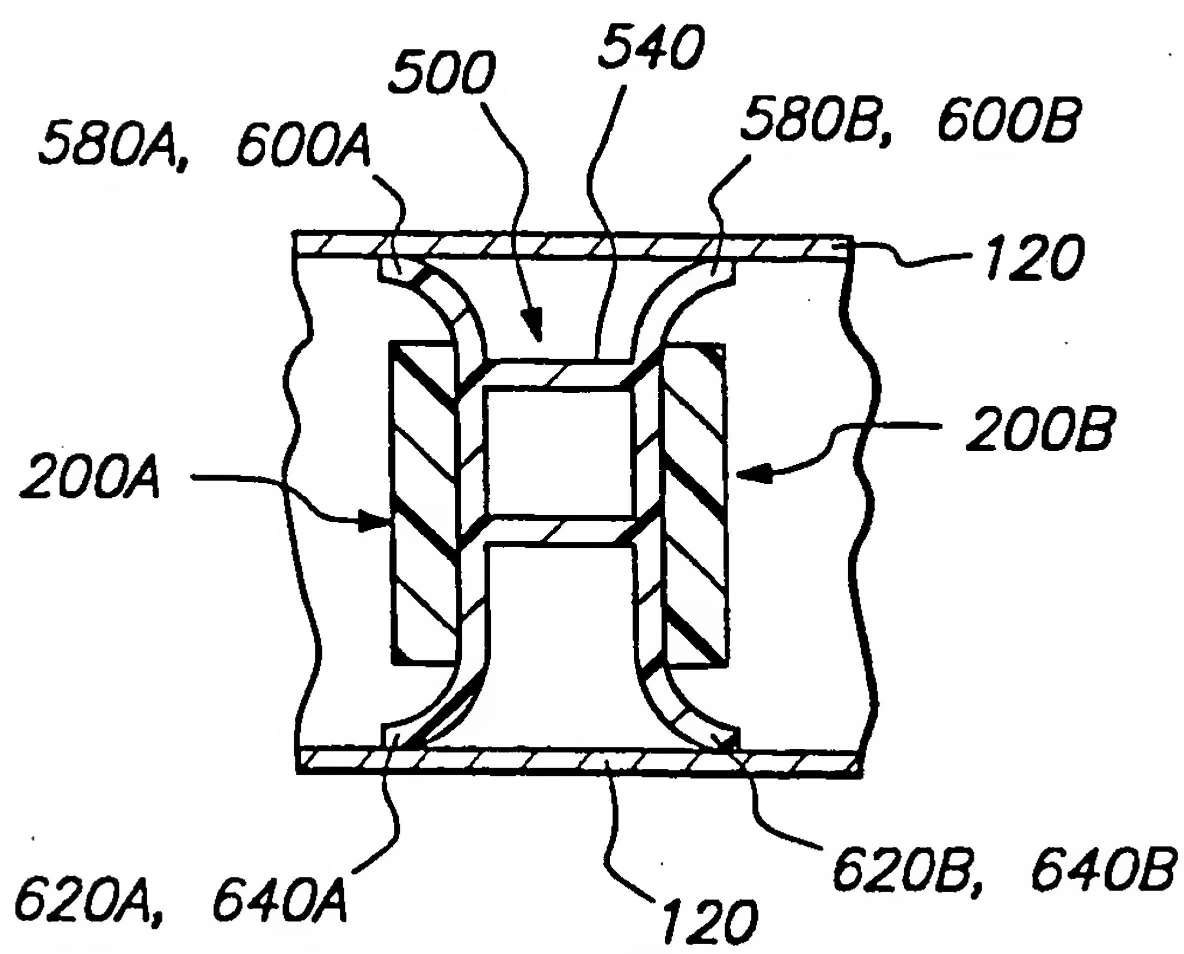

FIG. 18

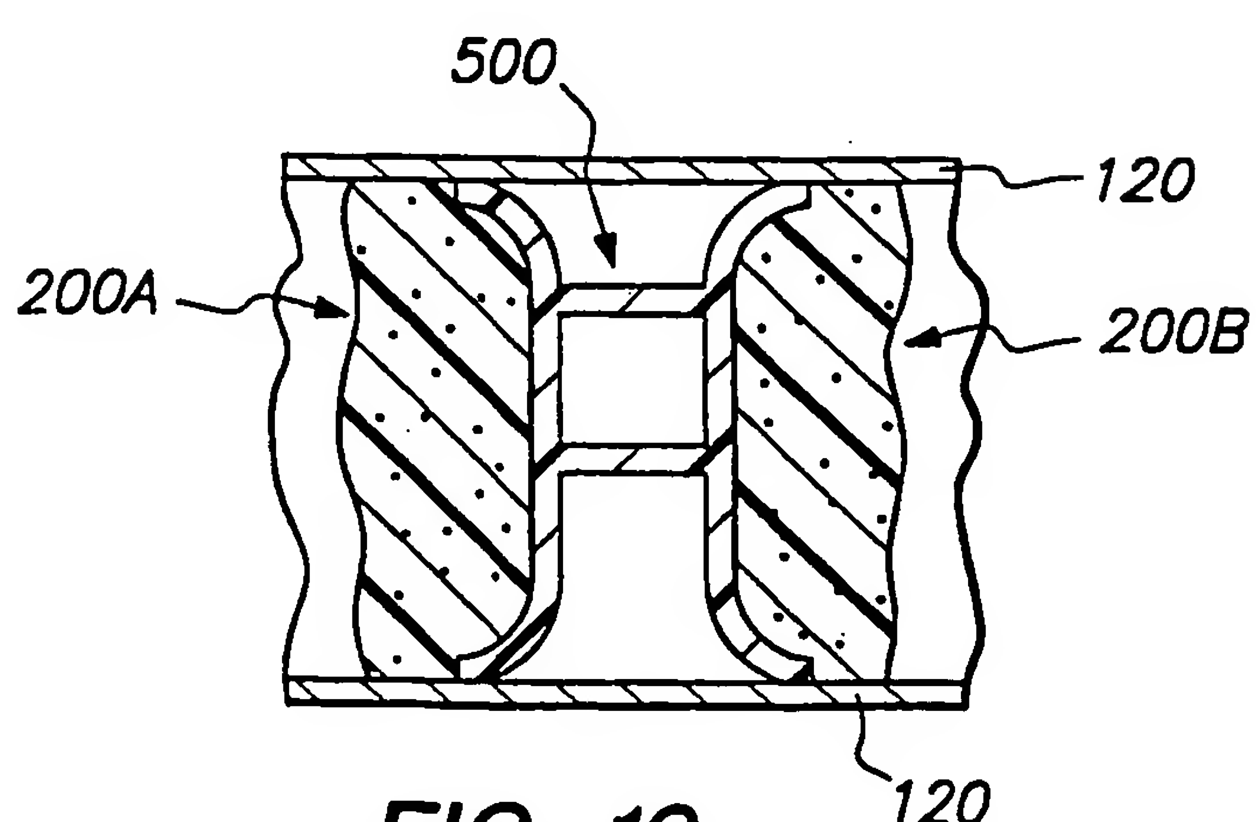

FIG. 19

INTERNATIONAL SEARCH REPORT

Inte nal Application No
PCT/US 98/03234

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B60R13/02 B60R13/08 G10K11/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B60R G10K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 898 630 A (O. KITOH) 6 February 1990 see the whole document ---	1-20
A	US 4 874 650 A (O. KITOH) 17 October 1989 cited in the application see the whole document ---	1-20
A	WO 93 11001 A (H. WALLENDY) 10 June 1993 see the whole document ---	1
A	EP 0 730 999 A (NEO-EX LAB. INC.) 11 September 1996 see figures 1-11 -----	2-4

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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4 June 1998	10/06/1998

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Information on patent family members

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